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OPERATIONS DIVISION

A DESCRIPTION AND SAFETY ANALYSIS OF SOLID RADIOACTIVE WASTE STORAGE FACILITIES AND PROCEDURES AT THE OAK RIDGE NATIONAL LABORATORY

F. T. Binford and J. R. Gissel

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UNION CARBIDE CORPORATION
for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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PREFACE

Responsibility for the operation and maintenance of the facilities for the disposal and storage of solid radioactive waste at the Oak Ridge National Laboratory was assumed by the Operations Division in July 1973. Previously, this responsibility had been delegated to the Field, Transportation, and Support Services Department of the Plant and Equipment Division. Personnel of the latter Division continue to supply many of the required functions under the direction of Operations Division supervision.

This analysis, prepared by the Operations Division, is intended to serve two purposes: first, to provide a reference description of the waste collection, handling, and storage operations and of the facilities utilized in these operations; and second, to identify the existing and potential hazards associated with the operations and to delineate the methods and procedures used to mitigate those hazards.

The analysis is believed to contain the best information available at the time of its preparation, January 1974, and does not, of course, reflect any information, procedure modifications, or changes in philosophy that may have taken place subsequent to that time.

Although some descriptive material concerning the handling of solid radioactive waste at the point of origin is included for completeness and continuity, that portion of the operation is beyond the scope of this review and most emphasis will be placed upon collection, transportation, and storage.

PART I. DESCRIPTION

PART I — DESCRIPTION

1. Introduction

Solid radioactive wastes generated at the Oak Ridge National Laboratory are collected in suitable containers and periodically transported to one of the solid waste storage areas (SWSA), commonly called "burial grounds," where they are stored either above or below the land surface in either a "retrievable" or "semi-retrievable" form.*

There are a number of different types of containers used for the collection of wastes at the point of origin. These vary in size and construction depending upon the character of the radioactive materials involved. In some cases the containers are reusable and, with proper precautions, are emptied into larger receptacles for transport. In other cases, the container is stored along with the waste.

There are six solid waste storage areas located on the Atomic Energy Commission reservation in the vicinity of ORNL. Two of these areas are inactive, and three (SWSA-3, -5, and -6) are currently in use, although SWSA-3 is now used only for aboveground storage of contaminated equipment that may be salveagable. The available space for semi-retrievable below-ground storage in SWSA-5 is nearly exhausted, although the area is still used for aboveground storage and for retrievable below-ground storage. SWSA-6 was opened in 1969, and contains sufficient space to handle the anticipated needs of the Laboratory until a more efficient method of handling solid waste is devised.

In Melton Valley, south of ORNL, where current operations are being carried on, there are few, if any, areas remaining suitable for use as solid waste storage areas.

2. Sources and types of wastes

Solid radioactive wastes are generated in a number of ways at ORNL. The largest volume consists of radwaste or "laboratory trash" (glassware, paper, rags, or other miscellaneous material) which is either contaminated or suspected to be contaminated. Other sources include solid residues from various physical and chemical processes. Frequently, contaminated items of equipment, machinery, tools, tanks, valves, pipes, etc., that are no longer needed are disposed of. Often, decontamination of each item to a level sufficiently low for conventional disposal is uneconomical; these items are disposed of by burial. An additional potentially high-volume source of solid waste is soil, concrete, and various types of building materials that have become contaminated as a result of leaks, spills, or by other means. These wastes also are usually buried.

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*In this context "retrievable" means the material is stored in durable containers in such a fashion that recovery of the material in the foreseeable future is facilitated. "Semi-retrievable" means that no particular attempt has been made to facilitate recovery, i.e., the material has simply been buried.

At one time the Laboratory's solid waste disposal areas were designated by the Atomic Energy Commission as the Southern Regional Burial Ground, and during the period from 1955 to 1963, about one million cubic feet of solid waste from various off-area sites was disposed of by underground burial in SWSA-4 and -5. Moreover, the waste storage areas have been, and continue to be, used occasionally for the disposal of waste from other government sites. The exact character of much of this waste is unknown.

Solid radioactive waste can be classified by physical size and shape, by type of contamination (i.e., β-γ, α, or fissile), and by the extent of contamination as measured either by the radiation intensity at the surface of the package or by the amount of transferable contamination on the package surface as determined by counting "smears."

Wastes handled routinely at the Laboratory can conveniently be classified for the purpose of storage in the following manner:

A. Fissile alpha waste* — solid waste that exceeds a concentration of 10 μCi/kg of alpha particle activity and is associated with fissionable isotopes. This category includes the transuranium isotopes (primarily Am, Cm, and Pu) as well as the isotope ^{233}U. These materials must be handled in such a manner as to contain the (generally long lived) alpha activity as well as with due regard for the criticality problems arising because of their fissile character. These materials originate primarily in the transuranium processing facility and as a result of fuel reprocessing operations. Frequently, beta-gamma activity is associated with these nuclides, and in some cases, notably those involving "even-even" nuclides of heavy elements, spontaneous fission occurs, thus creating a source of neutrons.**

B. Fissile non-alpha waste — solid waste that contains one gram or more of essentially non-alpha-emitting fissionable material regardless of concentration, or more than one gram per cubic foot of the same material regardless of quantity. In this context the term fissile applies almost exclusively to ^{235}U, because the other fissionable isotopes fall into the category of fissile alpha materials. Sources of ^{235}U waste include various metallurgical operations, residues from instrument applications, hot cell operations, and various research and analytical activities. The central problem here is to prevent inadvertent criticality.

C. General radioactive waste (radwaste) — solid waste that is neither fissile alpha nor fissile non-alpha as defined above. In general, this waste will contain beta-gamma activity and/or nonfissile alpha

*Corresponds to Transuranium-Contaminated Solid Waste as defined in AEC Appendix 0511, Part 1, B.23.a.

**In this connection, beryllium and deuterium become neutron sources when exposed to photons of sufficient energy. Because of this possibility, combinations of these nuclides with high energy gamma emitters must be handled in a special way.

activity (such as Po, Th, Ra, ^{238}U, etc.) and originates in many places in the Laboratory: reactor sites; radioisotope operations; particle accelerator areas; hot cell operations; various physical, chemical, and biological research areas; and analytical laboratories. It constitutes by far the bulk of the solid radioactive waste generated at the Laboratory.

General radwaste is further divided into two types depending upon the intensity of the radiation at the surface of the package. "Low level radwaste" has a radiation intensity less than 200 millirads/hour, and "high level radwaste" an intensity greater than 200 millirads/hour.

Solid radioactive wastes that are handled according to the normal standard procedures developed for the three classes described above are designated as "routine" wastes. Occasionally, a circumstance arises where solid material must be handled in a special manner, for example, because an item is too large or awkward to be accepted in a routinely used container or because the radioactivity level is extremely high. In such cases, special procedures are developed to handle the situation, and wastes dealt with in this fashion are termed "non-routine." Non-routine wastes are classified in the same fashion as routine wastes, and all normal precautions are taken as well as any additional precautions dictated by the special handling procedures required.

Quite frequently both routine and non-routine wastes contain mixtures of two or more of the above classes, that is, fissile waste may be accompanied by beta-gamma emitting fission products, or both transuranium nuclides and ^{235}U may be present in the same package. Other combinations can also occur. In such cases the waste material is treated with due regard for all of the components present.

3. Handling of radioactive wastes at the point of origin

Waste at ORNL is handled in accordance with the intent of UCN Standard Practice Procedure D-5-15 (Appendix A). The initial handling and packaging of radioactive wastes at the point of origin is governed by two requirements: first, to protect personnel from exposure to direct radiation and contamination, and second, to ensure that the various classes of materials are placed in containers of a kind appropriate for the type of storage prescribed.

In order to protect personnel against radiation and contamination, waste containers in current use in operating areas should have a low radiation intensity at the surface and be essentially free of transferable contamination. Appropriate precautions have been established and are presented in the ORNL Health Physics Manual,[1] (see Appendix B).

Various types of containers are designated as "approved" containers for the different classes of solid radioactive waste. These are designed to provide adequate shielding where necessary, to be suitable for transport to the solid waste storage areas, and to be appropriate for the type of storage contemplated.

For the purpose of handling at the point of origin, low level general radwaste may be conveniently thought of in terms of very low level material that requires little in the way of special precautions but material that is sufficiently radioactive to require precautions as described in ORNL Health Physics Manual, Procedure 2.7 (Appendix C).

A. Fissile alpha waste

Fissile material must be handled and accounted for in accordance with ORNL Health Physics Manual, Procedure 2.4 (Appendix D), and thus, the amount of fissile material present in each package must be determined prior to its delivery for transport to the SWSA. These fissile alpha wastes, which originate primarily in the various transuranium processing activities, are regarded as among the most hazardous generated at ORNL. The requirement that storage operations be conducted in a manner which permits retrieval was initiated by AEC Immediate Action Directive No. 0511-21 and OR Immediate Action Directive No. 0511-13 and has since been developed into USAEC Manual, Chapter 0511 (Appendix E). Hence, wastes must be placed in suitable containers at the point of origin because facilities for repackaging are not available at the SWSAs. Three types of containers (Figs. 1a, 1b, 1c, 2, and 3) routinely used for packaging fissile alpha waste are concrete casks, stainless steel drums, and stainless steel capsules. The choice of package depends upon the amount of direct beta-gamma and neutron radiation associated with the contents, and in all cases, the originator is responsible for compliance with the health physics regulations regarding radiation and surface contamination.

B. Fissile nonalpha waste

Fissile material must be handled and accounted for in accordance with ORNL Health Physics Manual, Procedure 2.4 (Appendix D), and thus, the amount of fissile material present in each package must be determined prior to its delivery for transport to the burial ground. Fissile material must be packaged in containers (described under "General radwaste — low level") suitable for burial in auger holes, and in no case can a single package contain more than 200 g of fissile material unless prior approval is obtained from the ORNL Criticality Committee. The originator of the fissile waste is required to give notice of the pending need for service to the SWSA foreman.

C. General radwaste — low level

Each operation that involves handling of radioactive materials is supplied with approved disposal containers or "hot" cans (Fig. 4), properly labeled, to receive contaminated materials. The disposal containers lined with plastic bags, are for slightly radioactive waste materials.

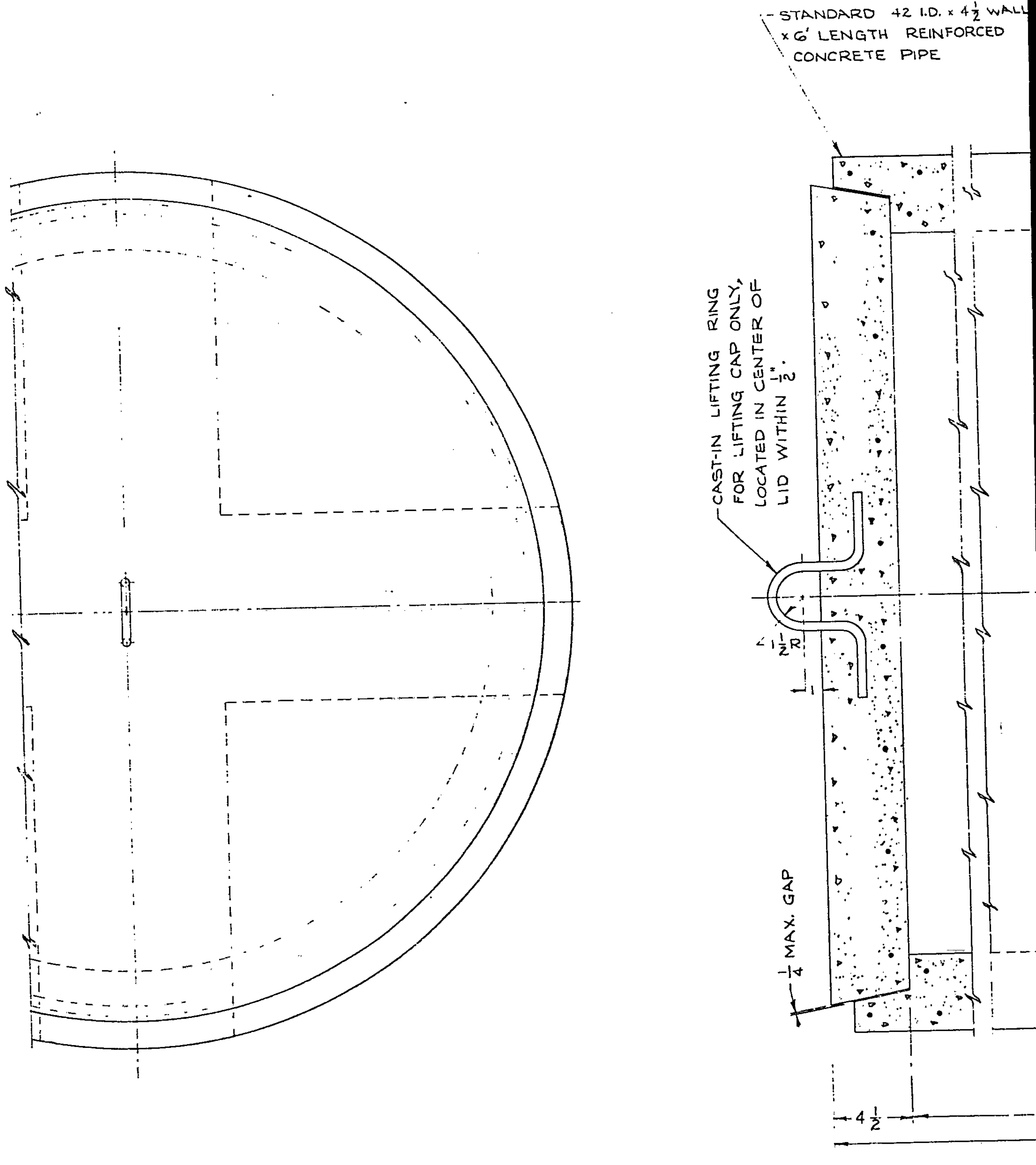


Fig. 1a. Concrete cask for st

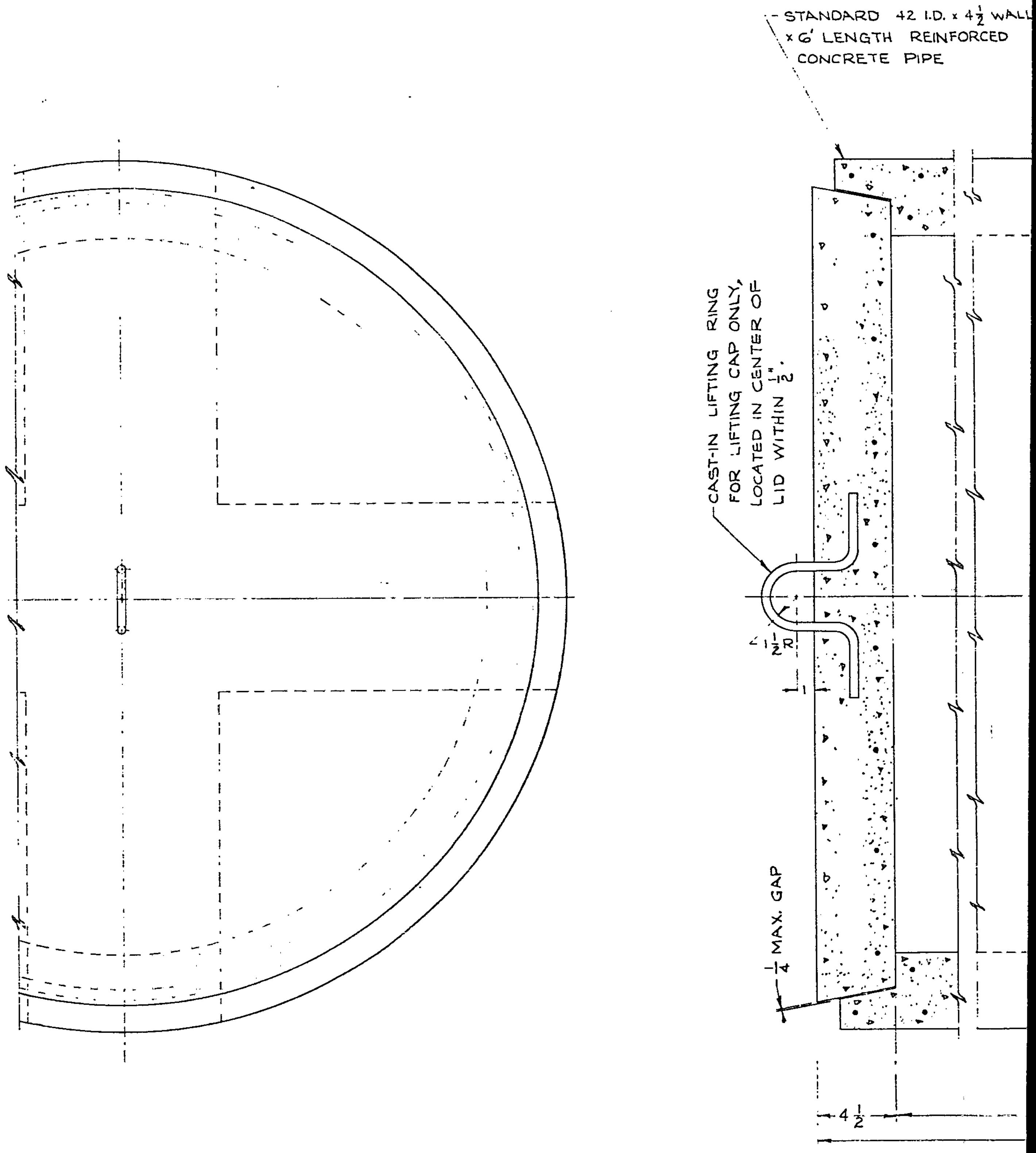
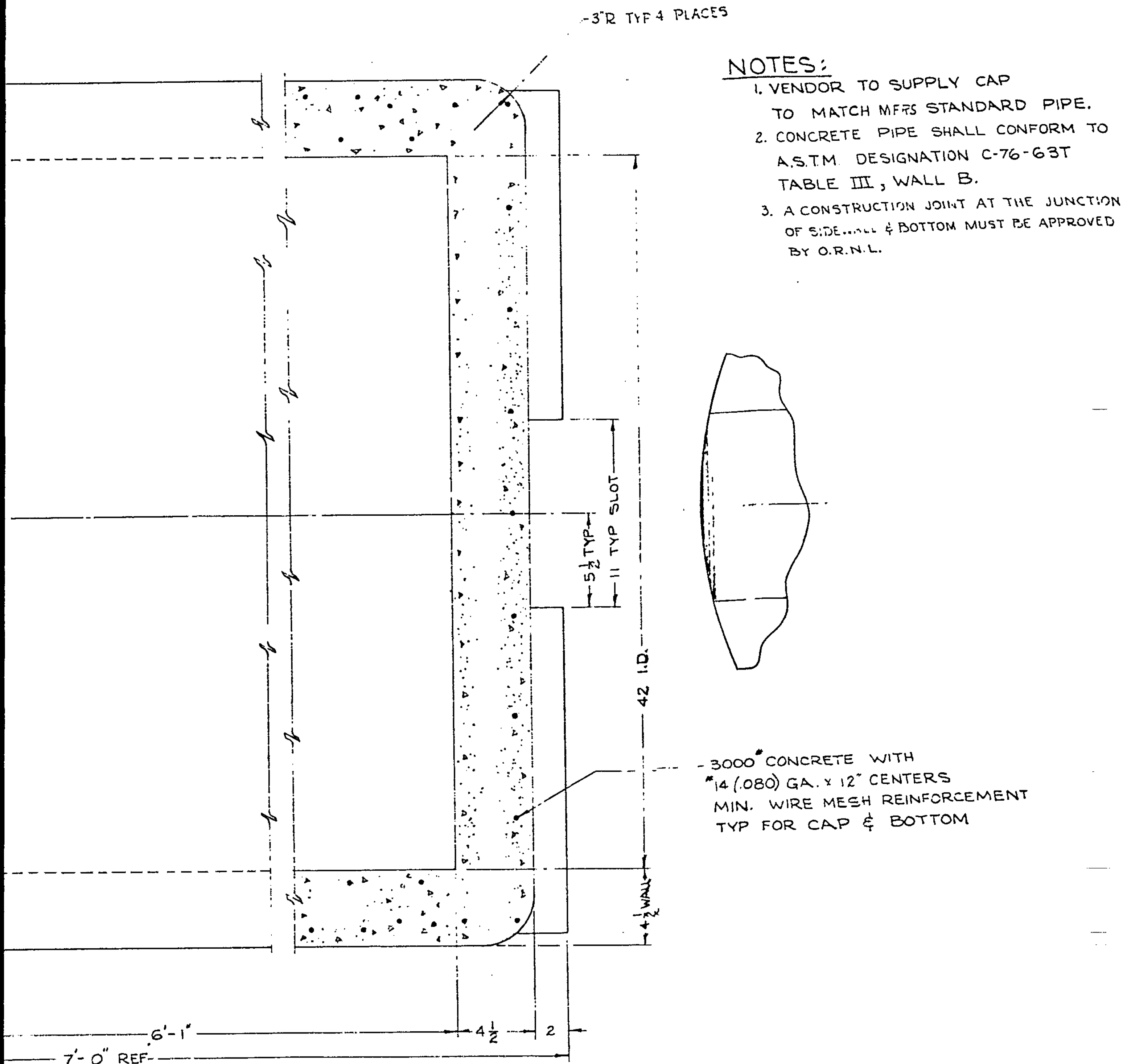


Fig. 1a. Concrete cask for sto



rage of fissile alpha wastes — thin walled.

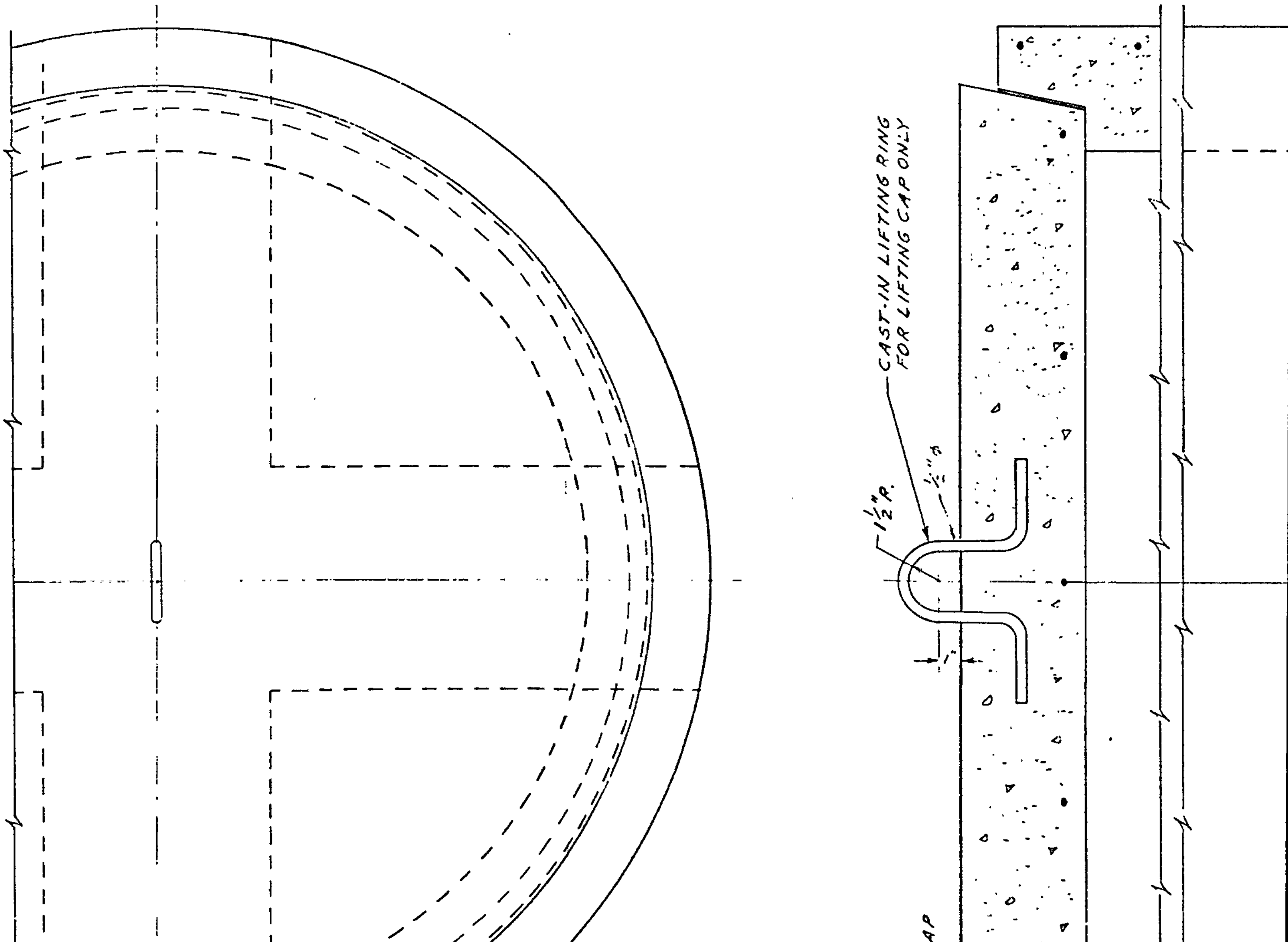
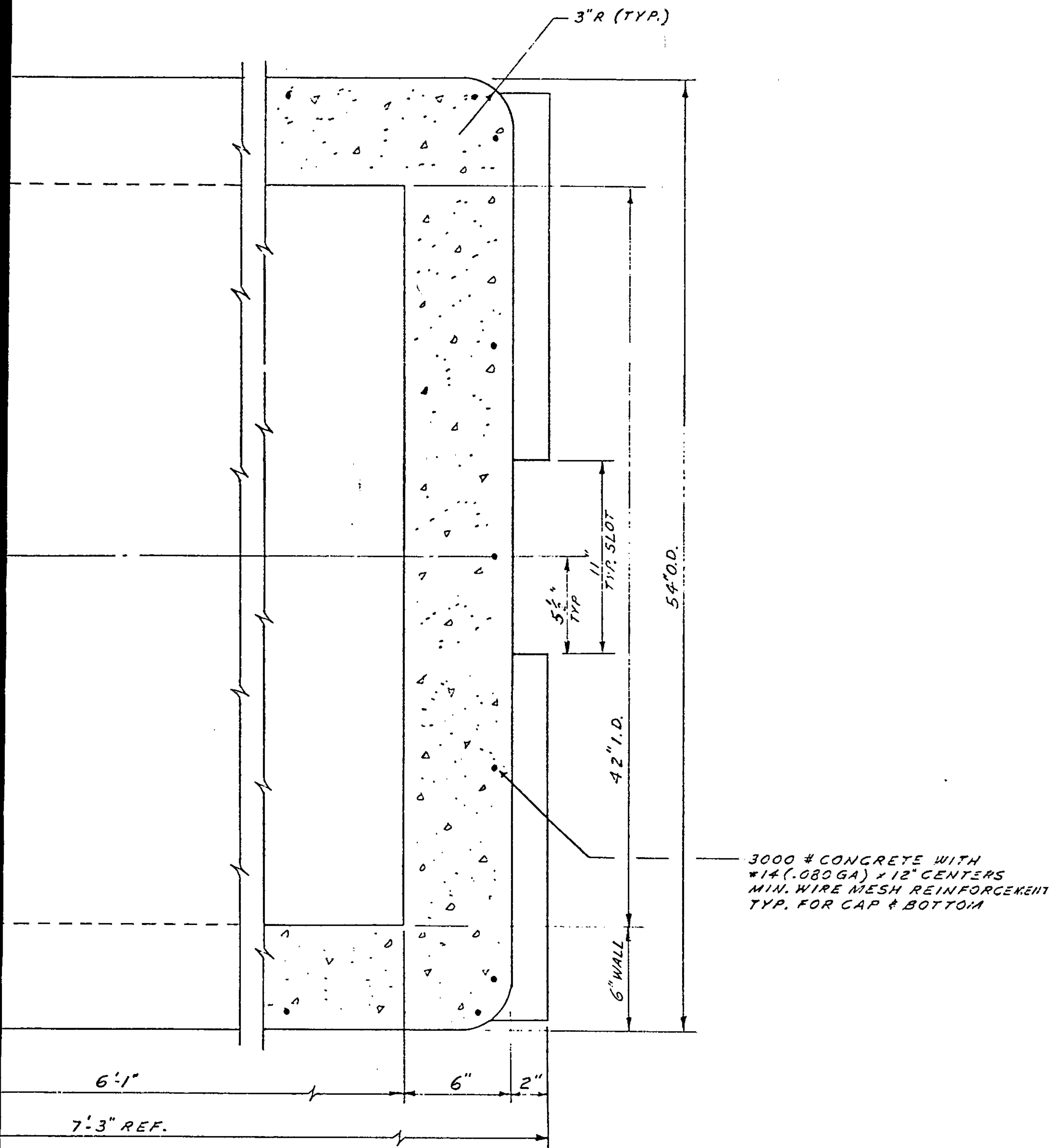


Fig. 1b. Concrete cask for storage of fissi



le alpha wastes — intermediate walled.

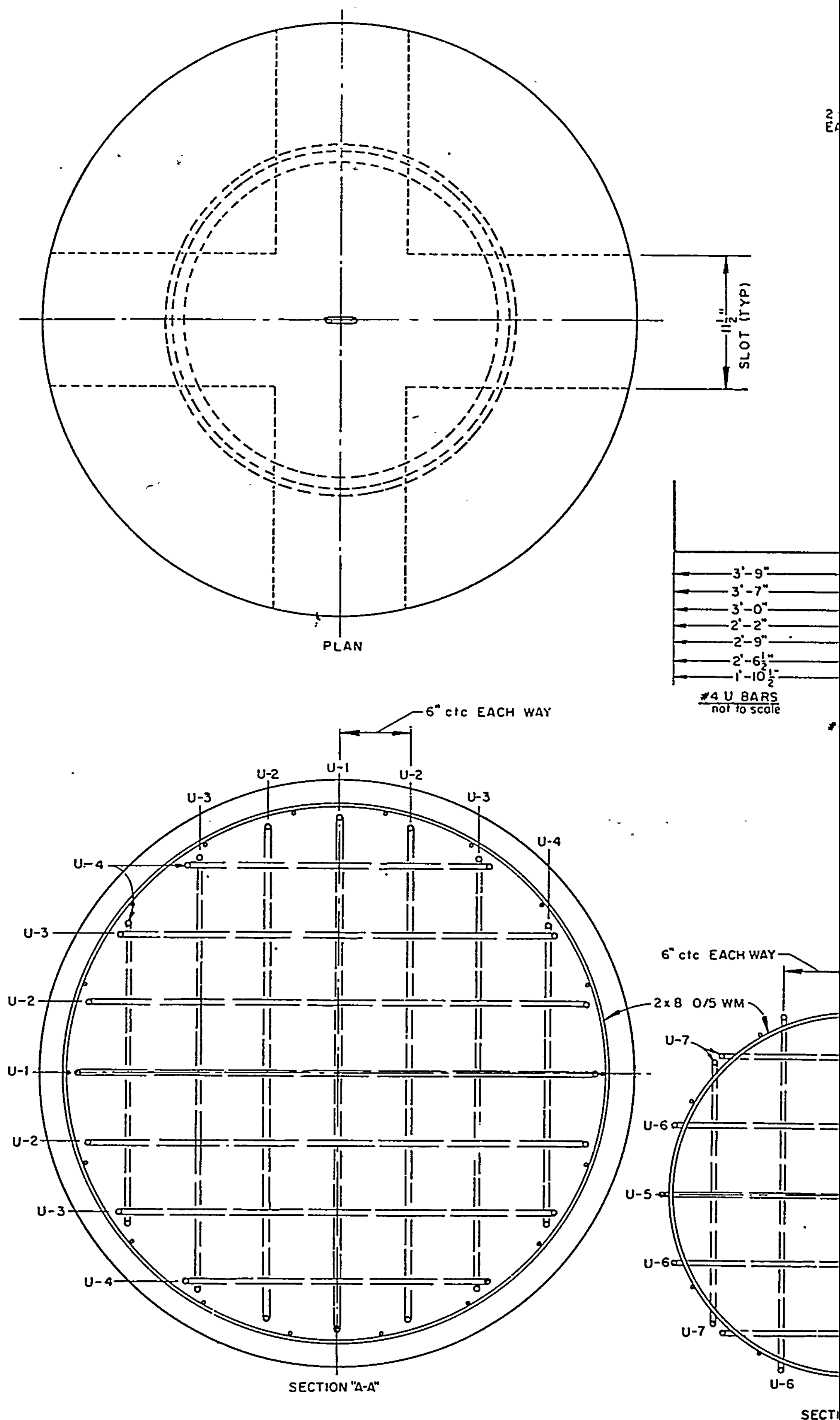
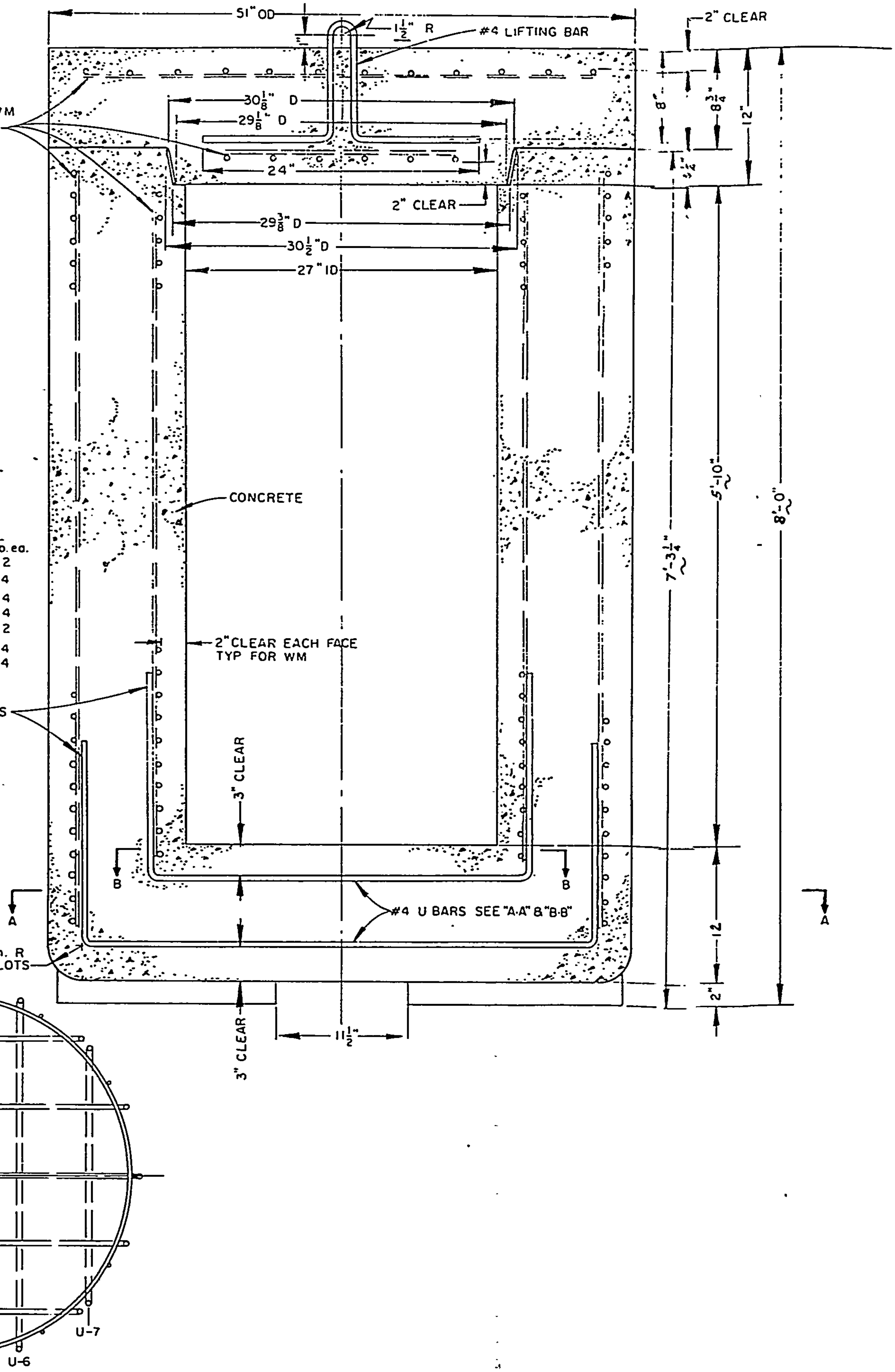


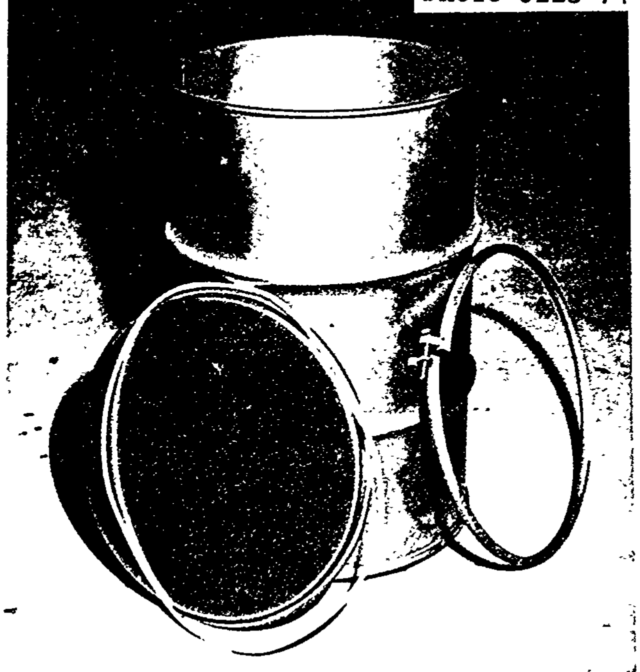
Fig. 1c. Concrete cask for storage o



sile alpha wastes — thick walled.

Figs. 2 & 3. Stainless steel drum (Fig. 2) and capsule (Fig. 3) for storage of fissile alpha waste.

PHOTO 0223-74



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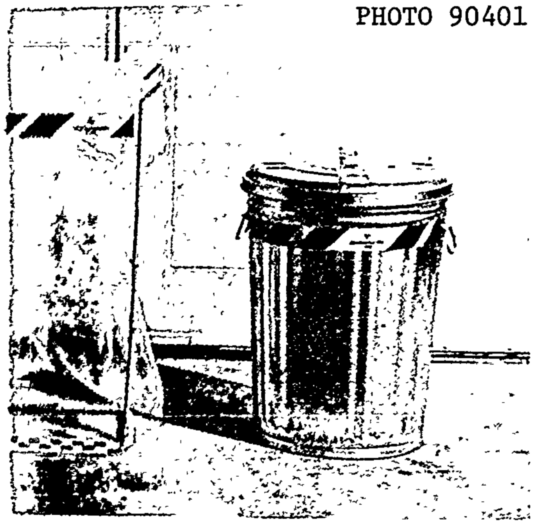

Fig. 4. Contaminated waste disposal containers.

When a container is full, the operator or technician responsible for waste removal from that particular operating area seals the plastic container and empties the can into the nearest yellow dumpster (Fig. 5) for removal to one of the solid waste storage areas. New plastic liners are installed and the can is reused. Members of the Radiation Safety and Surveys Section of the Health Physics Division periodically survey the containers to ensure that radiation and contamination levels remain below the specified limits. If necessary, the cans are decontaminated and, in some cases, disposed of.

PHOTO 64883

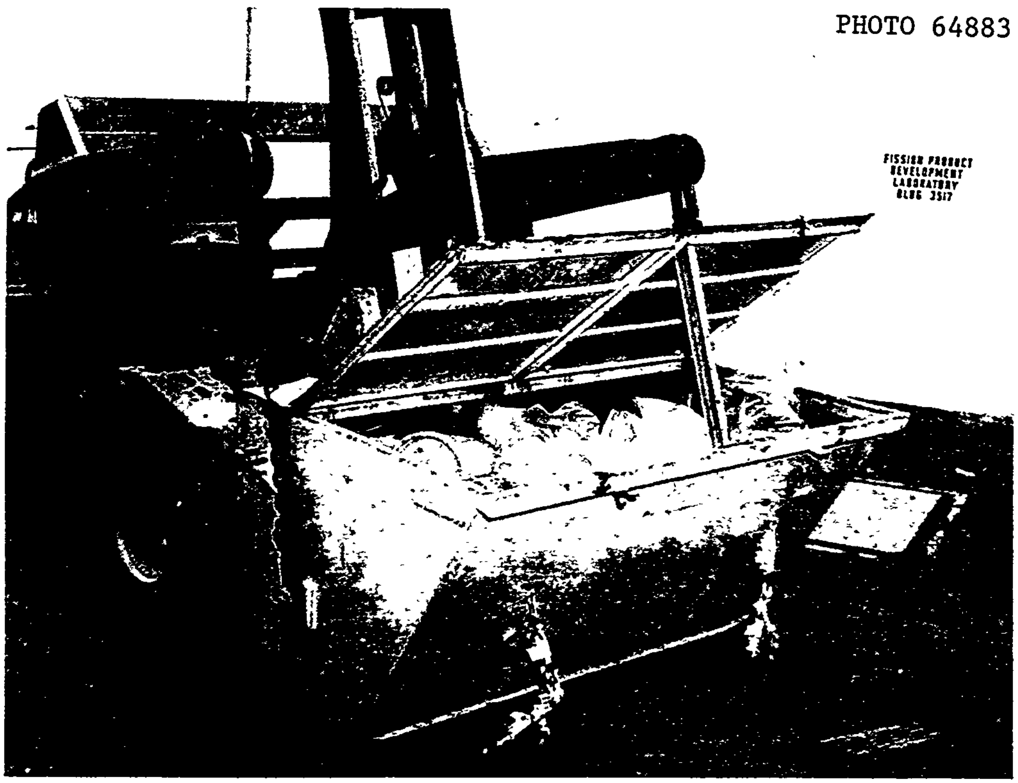

Fig. 5. Dumpster for low level waste disposal.

Low level materials that contain significant quantities of activity are handled very carefully to prevent direct radiation doses to personnel or the spread of contamination. Rather than being placed in reusable containers, these materials are generally placed in disposable cans or boxes. Inexpensive cans (Fig. 6) with 1-, 2-, 10-, and 20-gal capacities are available from ORNL stores, and are used as containers for the contaminated waste.

Normally, contaminated waste at this level is removed from the building as soon as possible to reduce the potential for personnel exposure. The surface contamination on the cans is determined by "smearing;" and, if specified limits are exceeded, the can is sealed in a second clean can prior to deposition in a yellow dumpster.

PHOTO 65303

Fig. 6. Waste disposal cans.

Disposal cans or bins appropriately labeled for collecting contaminated gloves, shoe covers, coveralls, etc., are available in those areas requiring this service. These materials are handled under the same rules as low and intermediate waste with the exception that all washable items reading less than 20 millirads/hr beta-gamma and 25,000 dis/min/100 cm^2 alpha are sent to the ORNL Laundry.

D. General radwaste — high level

High level waste usually originates in hot cells or in radiochemical or reactor operations and frequently must be loaded remotely and shielded prior to removal.

To remove high level wastes from a hot cell, barricade, or other source location, the radioactive material is first reduced to the smallest volume practicable and then loaded in a suitable container or can similar to those described above. In some cases, the container is sealed in plastic or the contents are sealed in plastic prior to being placed in the can.

High level wastes are not removed from the point of origin until a proper shielding device is available to receive the package. These devices may take the form of a specially shielded can or a bottom discharge carrier (Fig. 7). Lead shielded dumpsters (Fig. 8) are available to transport highly radioactive material to the storage areas, and in some instances, a truck with a shielded cab (Fig. 9) is used.

For non-routine situations, special types of shielded containers may have to be fabricated to handle these high level wastes.

PHOTO 2663-72

Fig. 7. Bottom discharge carrier.

PHOTO 64875

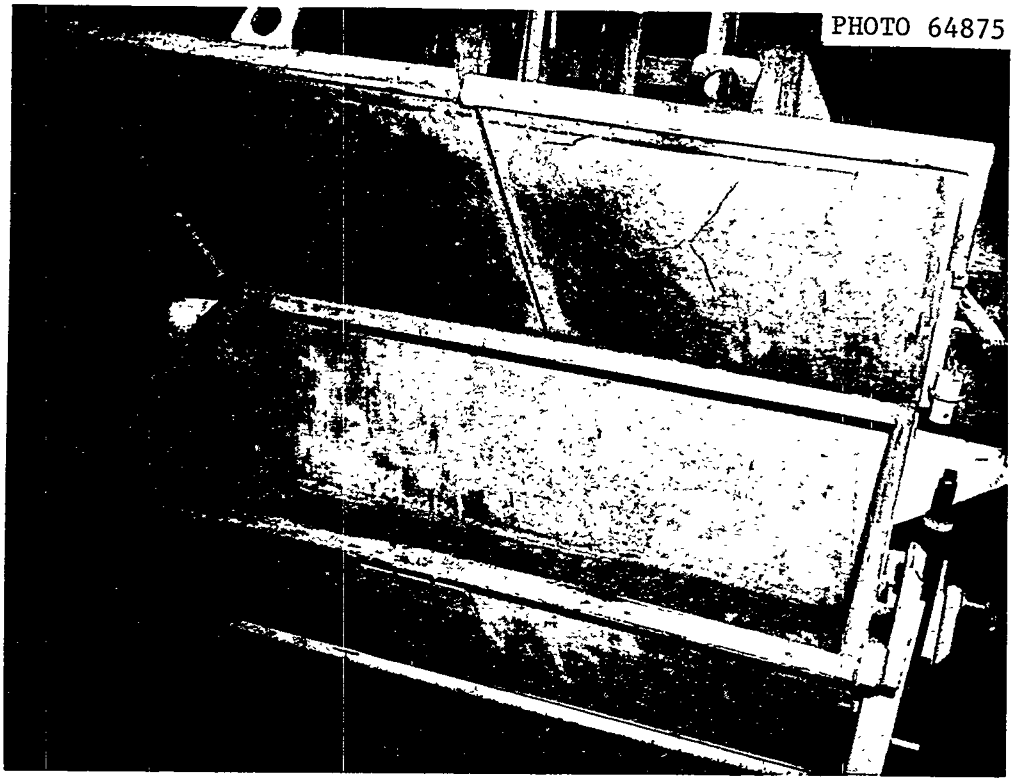

Fig. 8. Lead shielded dumpster.

PHOTO 0221-74

Fig. 9. Shielded "hot" truck.

4. Storage facilities

A number of different types of facilities are used for the storage of solid radioactive wastes. These range from trenches in which the material is placed and buried, to stainless-steel-lined auger holes for cylindrical drums or packages of various diameters, to aboveground, roofed buildings. The choice of facility depends on whether or not the material is to be retrievable and on the intensity and character of the radiation involved.

A. Fissile alpha waste

Solid fissile alpha waste, which consists primarily of trans-uranium isotopes and ^{233}U, is packaged in a manner appropriate to the radiation intensity associated with the waste. All of this material is now being stored in the retrievable mode.

Fissile alpha waste that is accompanied by high levels of beta-gamma or neutron emission is usually packaged at the source in a reinforced concrete cask (Fig. 1). These casks are available with three wall thicknesses, 4-1/2, 6, and 12 in. The loaded casks are transported from the point of origin by tractor-trailer and placed in trenches (Fig. 10) similar to those described in Section 4(C) by means of a mobile crane. The trenches are backfilled and can be identified by means of the metal casing or resurveyed from engineering data. Records are kept of the location and contents of each trench.

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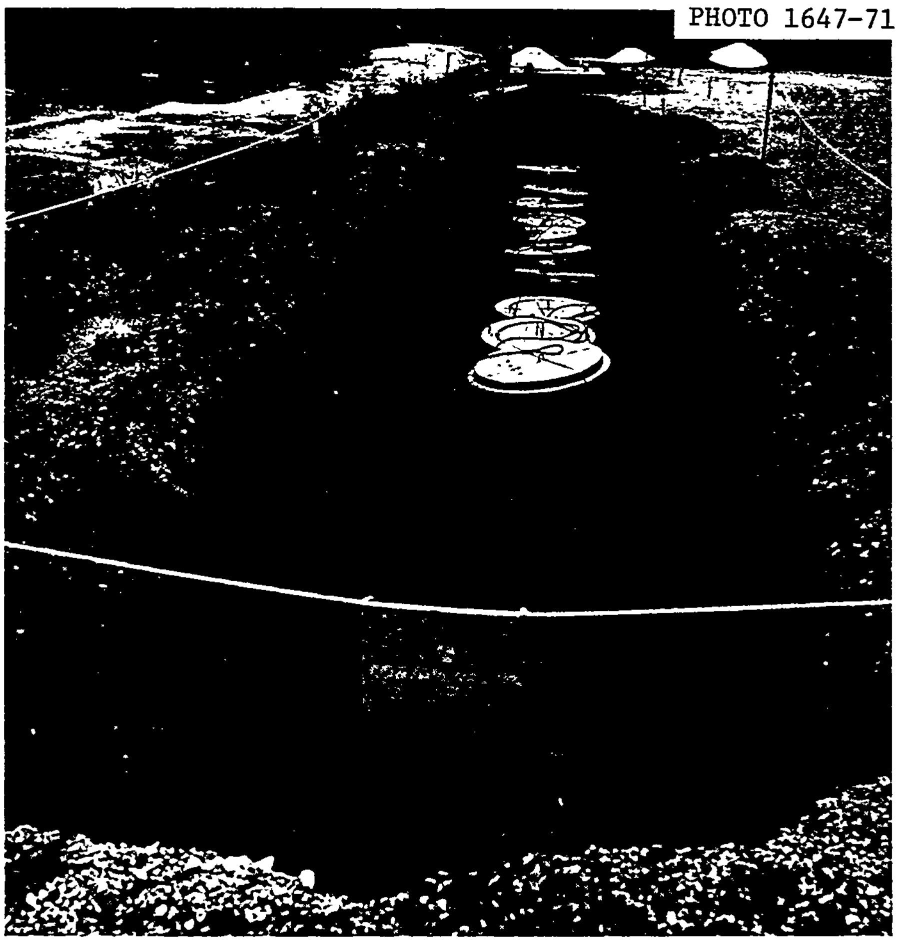


Fig. 10. Casks of fissile alpha material in disposal trench.

In cases where the radiation reading at the surface of the drums is less than 200 millirads/hr, the fissile alpha waste may be stored either in black iron or stainless steel drums or mild steel boxes in Building 7823 (Figs. 11a and 11b). A number of mild steel boxes containing slightly contaminated waste are stored in Building 7824. All material so stored is identified by metal tags, and all of the pertinent information is recorded and related to the tags.

Both buildings were constructed without benefit of formal design and were intended for temporary storage. They were erected primarily using discarded structural steel.

Building 7823 (Figs. 11a and 11b), which is 50 ft wide by 80 ft long two-thirds below grade, has a gable roof open at each end with a truck entrance on the south side of the building. The walls are curved galvanized metal culvert sections of 12-gauge corrugated steel. The roof is 0.032-in. corrugated aluminum with four sections of plastic skylight. There is an interior ceiling of 9-gauge galvanized steel wire fencing located 14 ft above the crushed rock floor. There are no utilities inside the building.

Funds have been requested to replace this building with a more suitable permanent structure; and when construction is complete, use of Building 7823 for retrievable storage will be discontinued.

Building 7824 was intended to be merely a sheltered work area and storage shed for nonradioactive material. It currently contains about 40 steel boxes containing slightly contaminated waste. These are to be disposed of below grade in the near future and use of the building for storage waste will be discontinued.

Criticality control of these materials is accomplished by imposition of the restrictions given in Table 1 that specify the maximum quantity of fissionable material* permitted in each type of container. These restrictions are consistent with the requirement that the concentration of fissionable material shall not exceed 5 g/ft^3, at which level an infinite array of such containers has a multiplication constant well below unity.[2] In any case, where the amount of fissionable material to be stored exceeds the quantities listed in Table 1, or 5 g/ft^3 for other containers, the originator of the waste must obtain prior approval from the ORNL Criticality Committee (Part I, Section 7). Under certain circumstances this Committee may, after due consideration, modify the requirements of Table 1 for individual packages.

In some cases fissile alpha material with high background readings is stored in stainless-steel-lined auger holes of various diameters — normally 8, 10, 12, 14, 16, or 30 in. (Fig. 12) — and drilled to meet the hydrological requirements outlined in Section

*Fissionable material means ^{233}U, ^{235}U, or ^{239}Pu. Very small quantities of transuranium isotopes may be present, some of which are fissionable. Control of these materials is discussed in Part II.

Fig. 11a. Exterior of building.

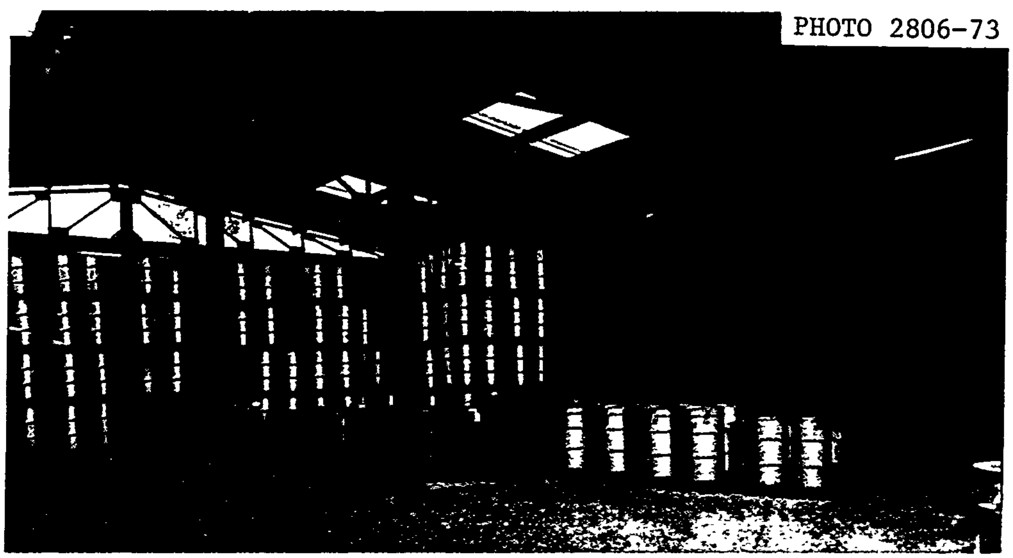


Fig. 11b. Interior of building.

Figs. 11a and 11b. Building 7823 for aboveground storage of fissile alpha waste.

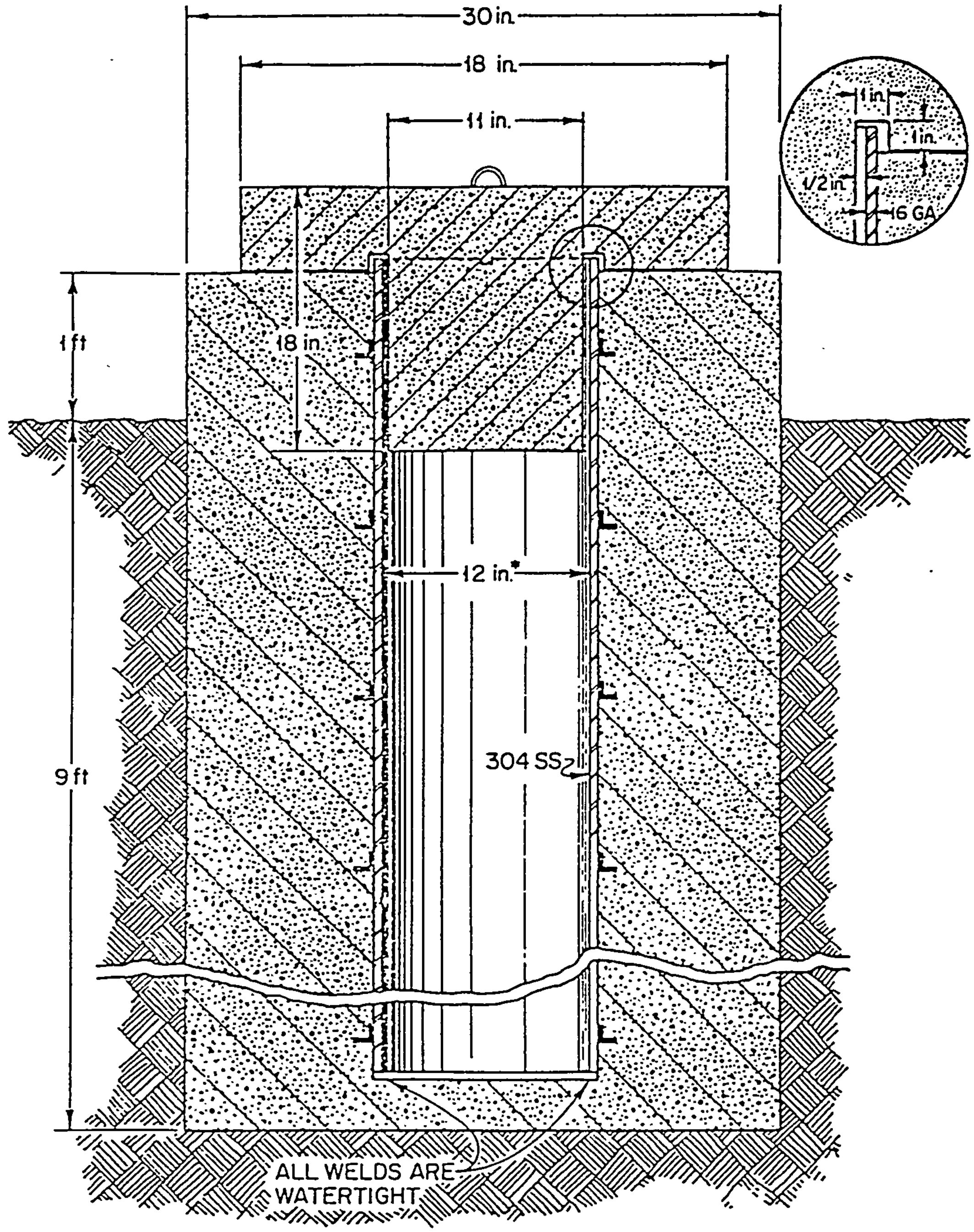


Fig. 12. Typical stainless-steel-lined auger hole for storing fissile alpha waste having high radiation reading. (Available also with 8, 10, 14, 16, and 30 in. I.D.)

4(C) for disposal trenches. The liners are rolled from 16-gage stainless steel and seam-welded; the bottoms are then welded in. All welds are dye-checked. The liners are provided with concrete collars and stainless steel caps. For criticality control, spacing between holes is not less than 3 ft, edge to edge, and the isotope content per hole is limited to 200 g unless prior approval is obtained from the ORNL Criticality Committee.

The holes are used to store waste contained in stainless steel 30- or 55-gal drums or in other suitable stainless steel cylindrical containers.

After each package is inserted, a quantity of sand is placed on top for shielding purposes. When full, the hole is plugged with a removable stepped concrete plug and a metal tag is provided for identification purposes. Records are kept of the contents of each hole.

Table 1. Amount of fissionable material permitted by container type

Container type	Maximum fissionable material (g)
30-gal drum	20
50-gal drum	36
Concrete cask (thin walled)	200
Concrete cask (intermediate walled)	200
Concrete cask (thick walled)	96

B. Fissile non-alpha waste

Uranium-235, uncontaminated with fissile alpha nuclides, is normally buried in containers in unlined auger holes. A restriction of 200 g per hole is imposed for criticality control. Prior approval of the ORNL Criticality Committee is required before this limit is exceeded.

The contents of these auger holes are logged and records are maintained. When filled, the holes are capped with concrete.

C. General radwaste

General radwaste storage is accomplished in nearly all cases by depositing the waste below grade in trenches or in auger holes.

All trench development is accomplished using good engineering practices, and due consideration is given to the topological and hydrological features of the site. The trenches are constructed and maintained to isolate the waste from surface and groundwater. The trenches are restricted to a length of 50 ft and a width not to exceed 10 ft. The depth is normally 10 to 15 ft and is always limited to at least 12 in. above the known high water table. If, due to unanticipated circumstances, the excavation falls below the water table, the trench is backfilled with Conasauga shale to a depth of at least 12 in. above the existing water.

The trenches are graded to slope toward one end (approximately 1/2-inch per foot of length). A 6-in. diameter, perforated, corregated metal casing, inserted vertically into the trench and extended above the surface of the ground, serves as a monitoring well. A typical layout of a disposal trench is shown in Fig. 13, and a photograph of such a trench is shown in Fig. 14.

Surface water drainage is controlled by ditching around the trenches to meet prevailing surface drainage requirements. Appropriate barricades are provided adjacent to the open portions of the trenches to ensure personnel safety.

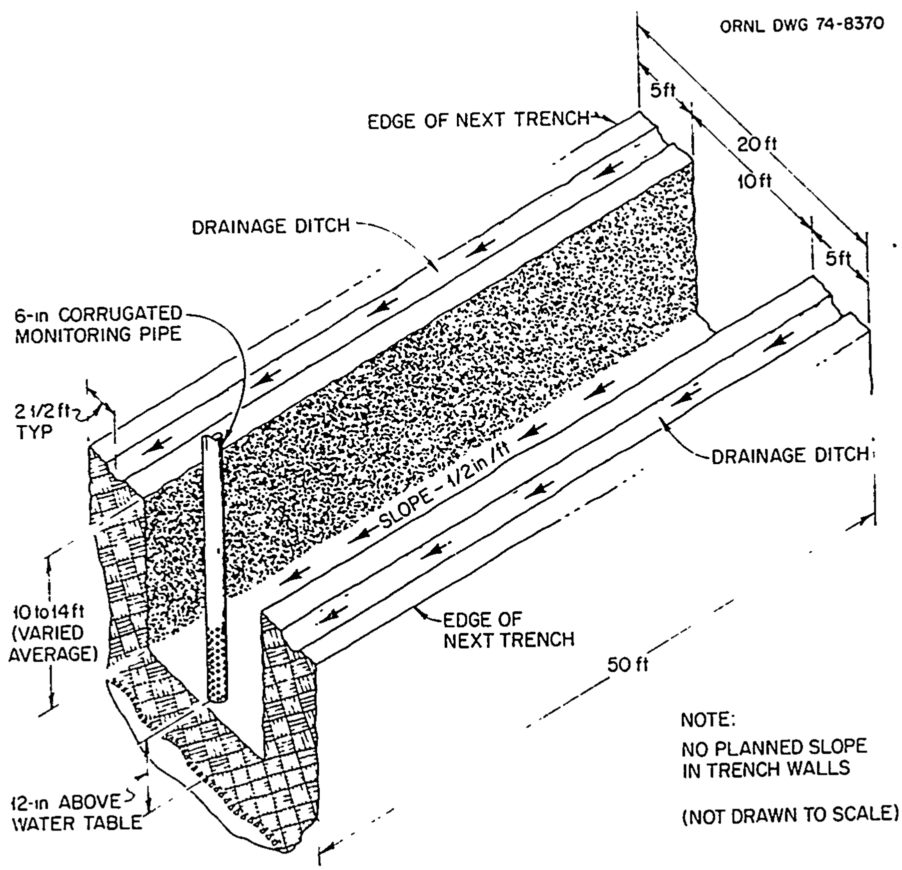


Fig. 13. Typical disposal trench layout.

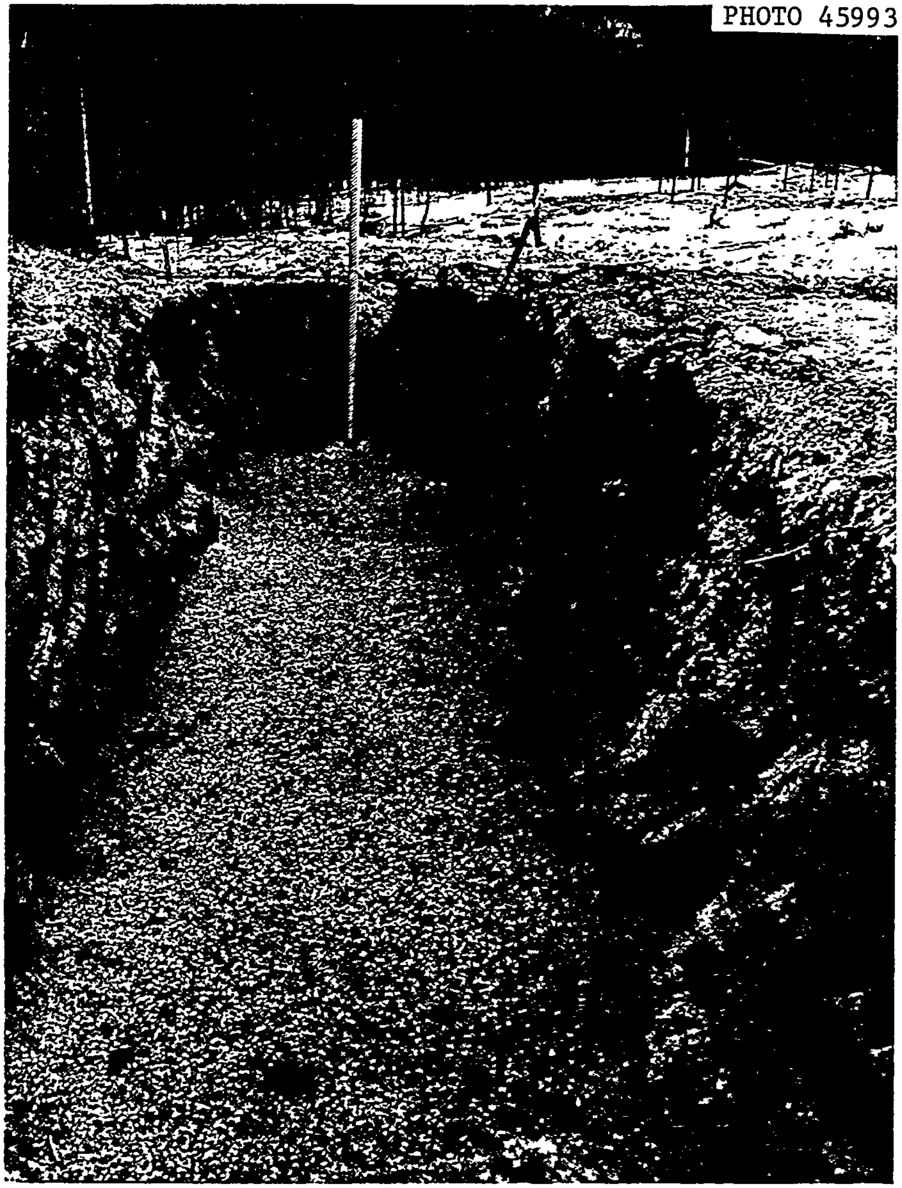


Fig. 14. Open waste disposal trench.

General radioactive waste is transported from the Laboratory to the trenches in dumpsters or other suitable containers and placed in the open trench, as shown in Figs. 15 and 16. Appropriate health physics procedures are used during these operations, including use of masks and protective equipment where required.

The dumpsters shown in Figs. 5 and 8 are large, covered, metal containers that can be transported by a specially built truck (Fig. 17).

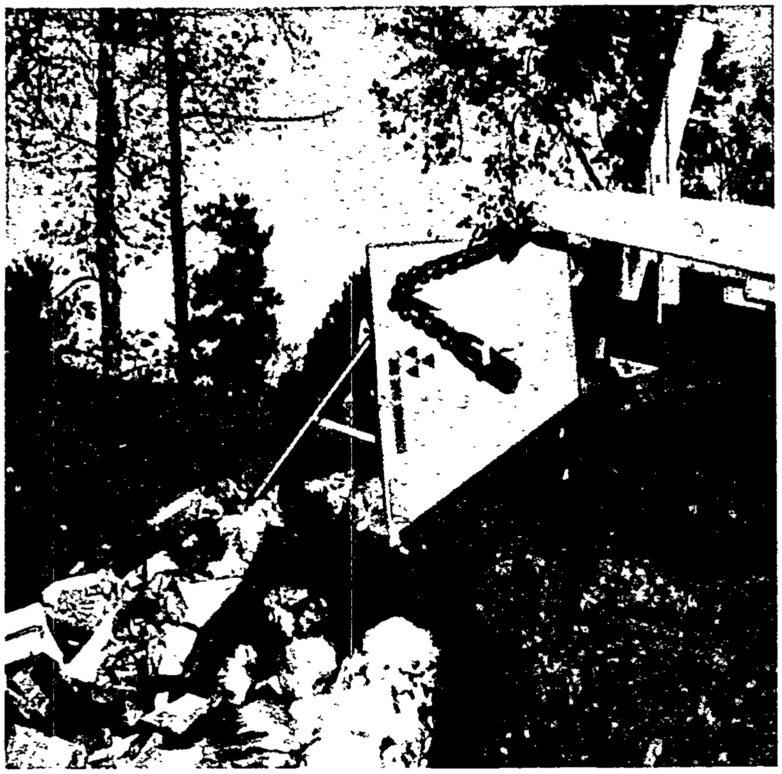


Fig. 15. Dumpster being emptied into a disposal trench.

PHOTO 101770

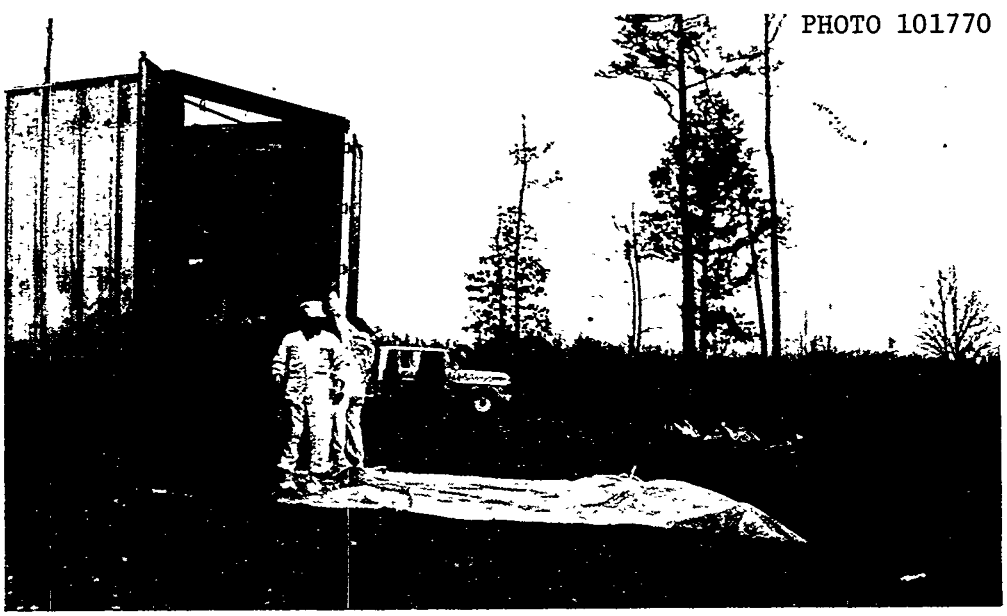


Fig. 16. Burial of disposable containers.

PHOTO 93431

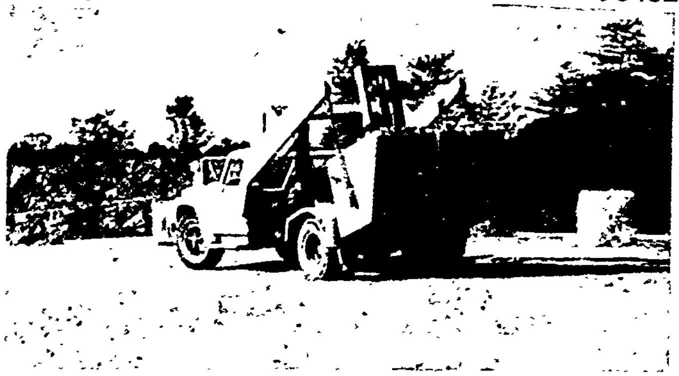


Fig. 17. Dumpster and truck.

Once the trench is filled to within 3 ft of grade, it is backfilled with earth cover over the waste. If periodic sampling of the well or other symptoms indicate that additional action is required to prevent the entry of water, appropriate steps are taken. The metal well casing is also used as a trench marker and may have a metal tag identifying the trench by number attached to it. All trench details are maintained on as-built drawings, and a log describing the history of the trench is maintained. Figure 18 is a photograph of a closed trench.

Fig. 18. Closed disposal trench.

Note that the foregoing procedures represent current practice in SWSA-5 and SWSA-6. Less careful attention was given to the selection of the other storage areas, and there was much less thought involved in the design of the trench configuration. These problems will be discussed again in Part I, Section 5 and in Part II.

5. Solid waste storage areas

Storage of solid radioactive waste was initiated by the Manhattan District in the early 1940's at what is now ORNL. Locations for the first three SWSAs were selected primarily for convenience and few, if any, geologic or hydrologic considerations entered into the siting decisions. However, as the volume of waste generated at ORNL increased and the quantity and variety of solids from offsite agencies expanded, greater attention was given to the selection of sites for storage areas.

It was determined that areas underlain by Conasauga shale formations make excellent sites for underground storage,[3] not only because the shale is easily excavated, but because the ion exchange properties of this material inhibit the migration of water soluble nuclides through the soil. Because the area in Melton Valley, south of ORNL, is underlain by this formation, it has been used as a site for the three SWSAs opened since 1951. Aerial photographs showing the locations of the six SWSAs are displayed in Figs. 19 and 20.

Of the six SWSAs at ORNL, only two are currently in use, although another (SWSA-3) is used occasionally for aboveground storage of reusable equipment. Table 2 shows the current operational status of the ORNL solid waste storage areas.

Table 2. Operational status of ORNL solid waste storage areas

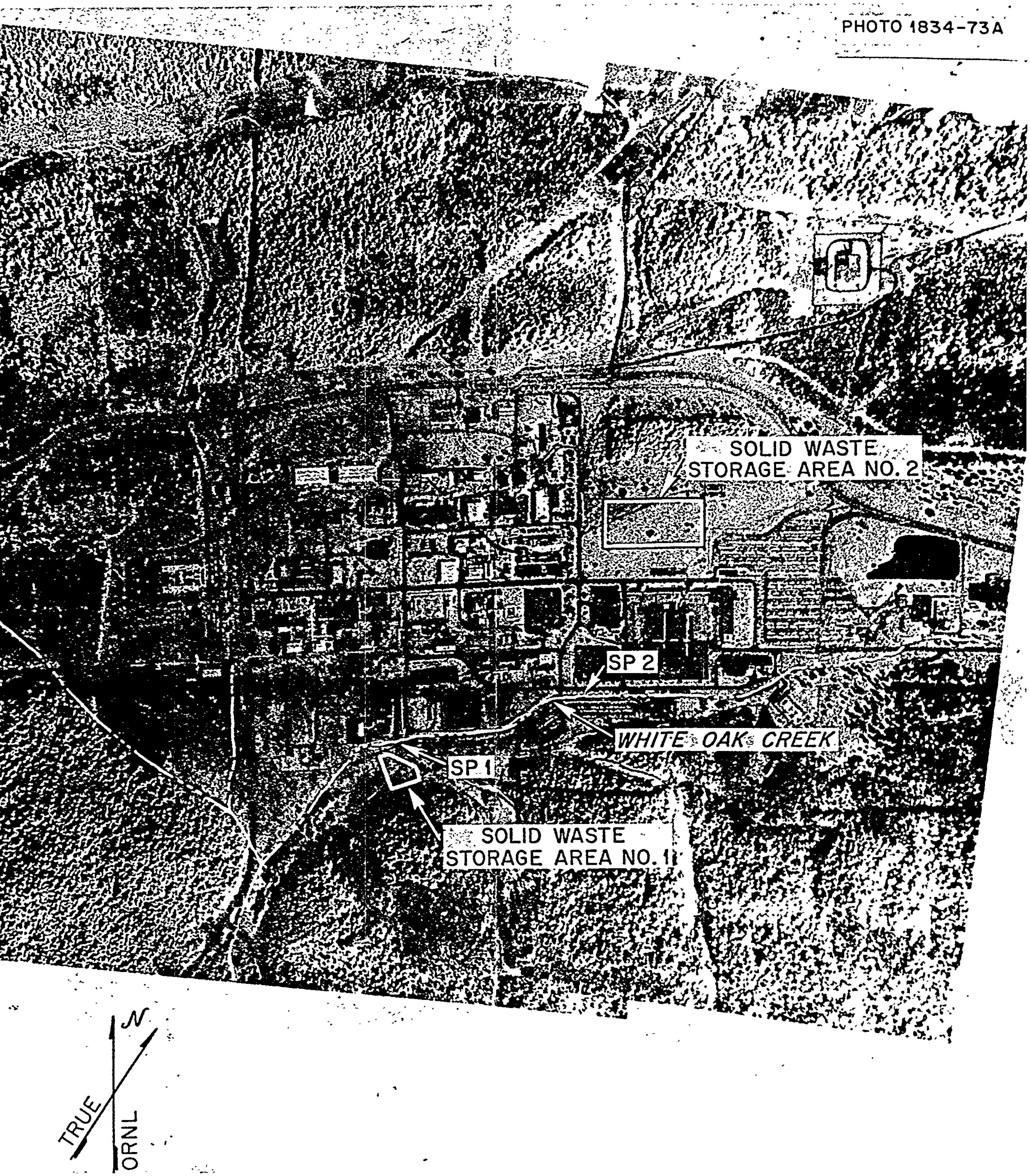
SWSA	Operating dates	Status	Land used (acres)
1 and 2	1943-1946	Closed	5
3	1946-1951	Closed	7
4	1951-1959	Closed	23
5	1959-	Operating	33
6	1969-	Operating	68

The following descriptions of the solid waste storage areas reflect an awareness of the problems associated with solid waste storage which has evolved over the years.

A. SWSA-1, -2, and -3

These areas are located in Bethel Valley at the main ORNL site. SWSA-1 and -2 are relatively small, covering a total of about 5 acres, and were closed by 1946. Wastes were merely dumped into the open trenches that were then backfilled. The locations of these "burial grounds" are shown in Fig. 19, and Fig. 21 is a photograph of the Clinton Laboratory (now ORNL) showing the two areas during the time they were in use. There are no available records showing the quantity or kind of solid waste disposed of in these areas; however, because of the close accountability exercised at that time and the extreme value placed on the material, very little fissionable material was disposed of in these areas. Moreover, large quantities of radioactive material had not yet become available so the amount of radioactivity present is also presumed to be small.

Fig. 19. ORNL-Bethel Valley



waste disposal facilities.

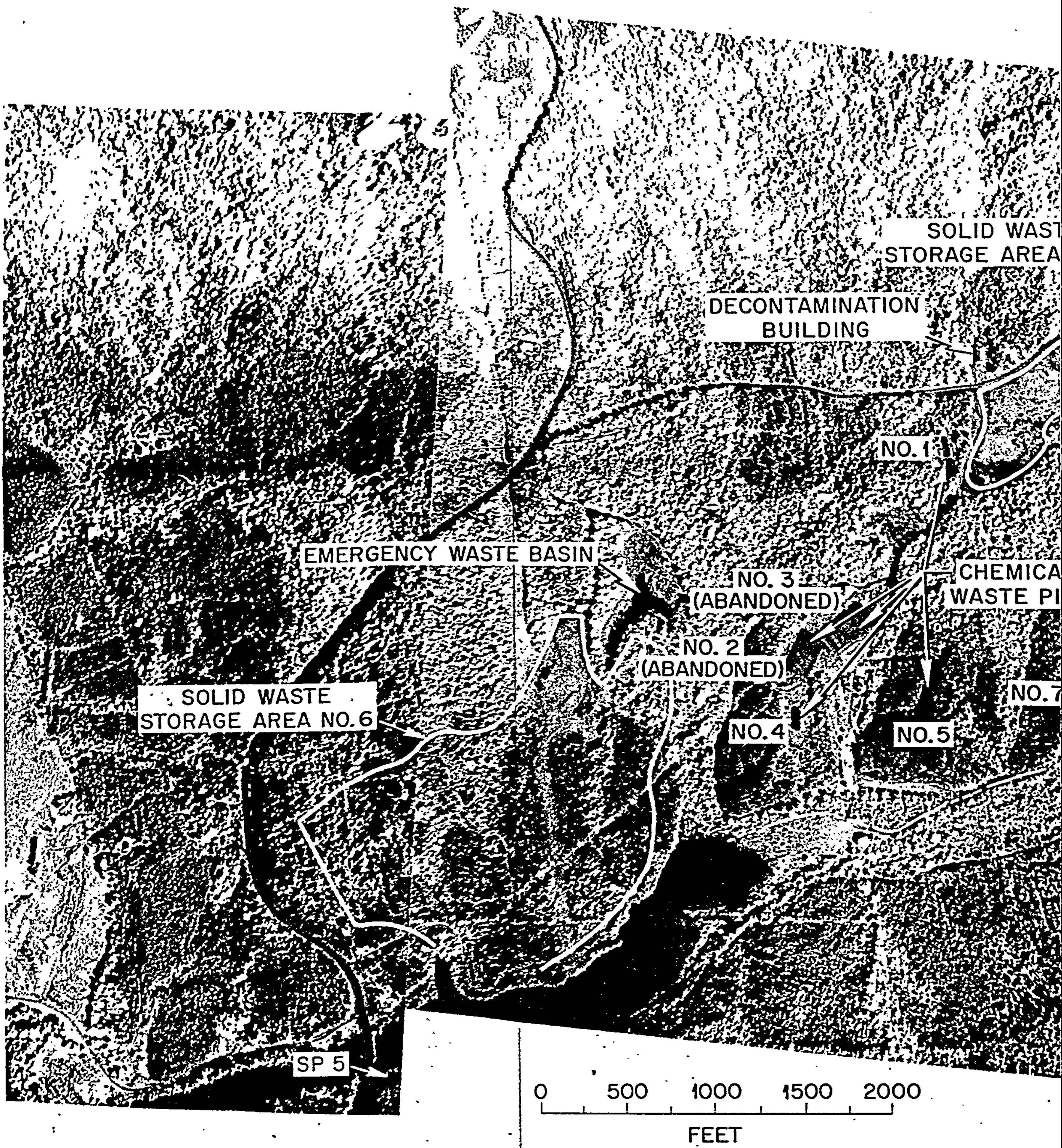
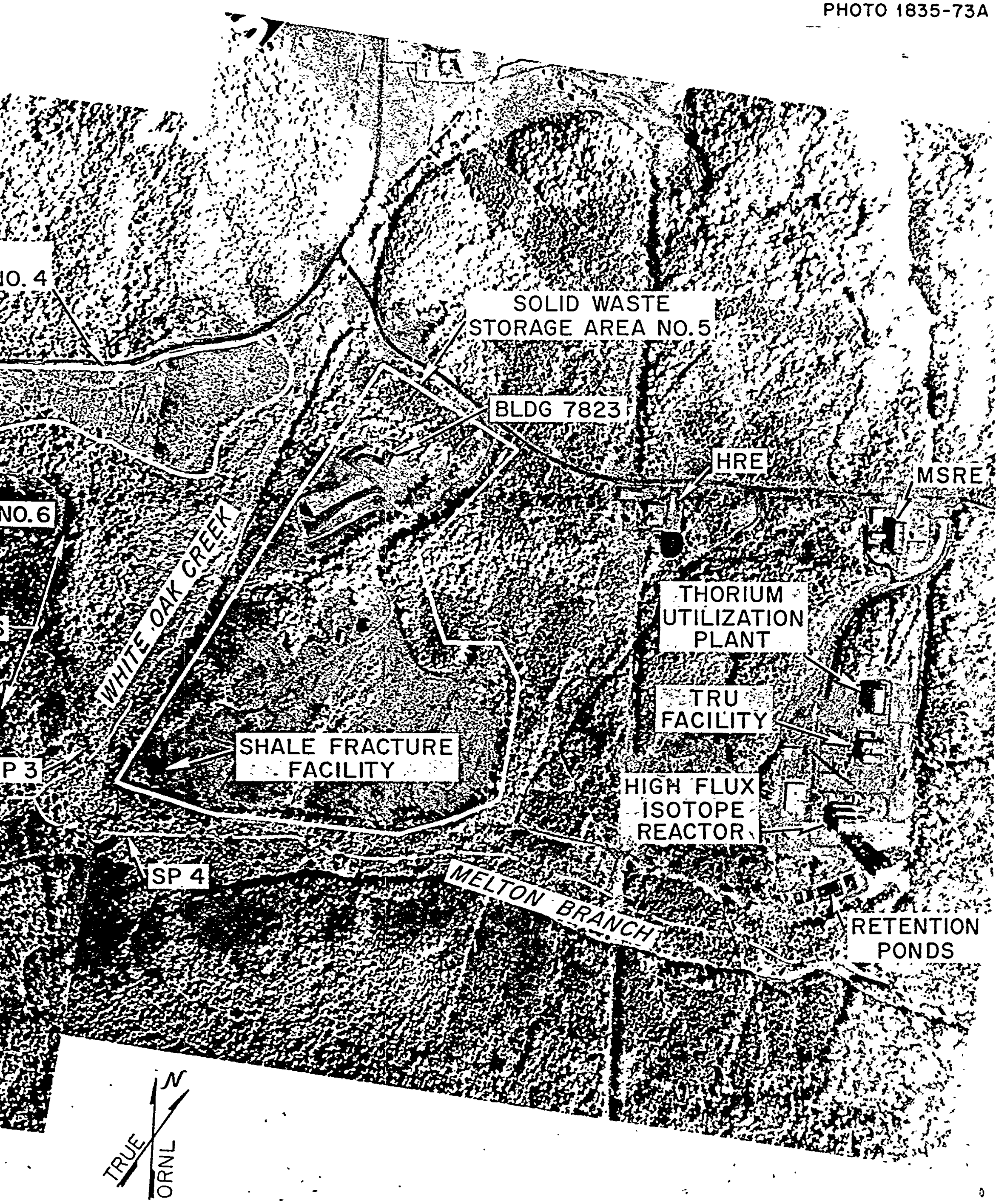


Fig. 20. ORNL–Melton Valley wa

PHOTO 1835-73A



e disposal facilities.

PHOTO 0518-74

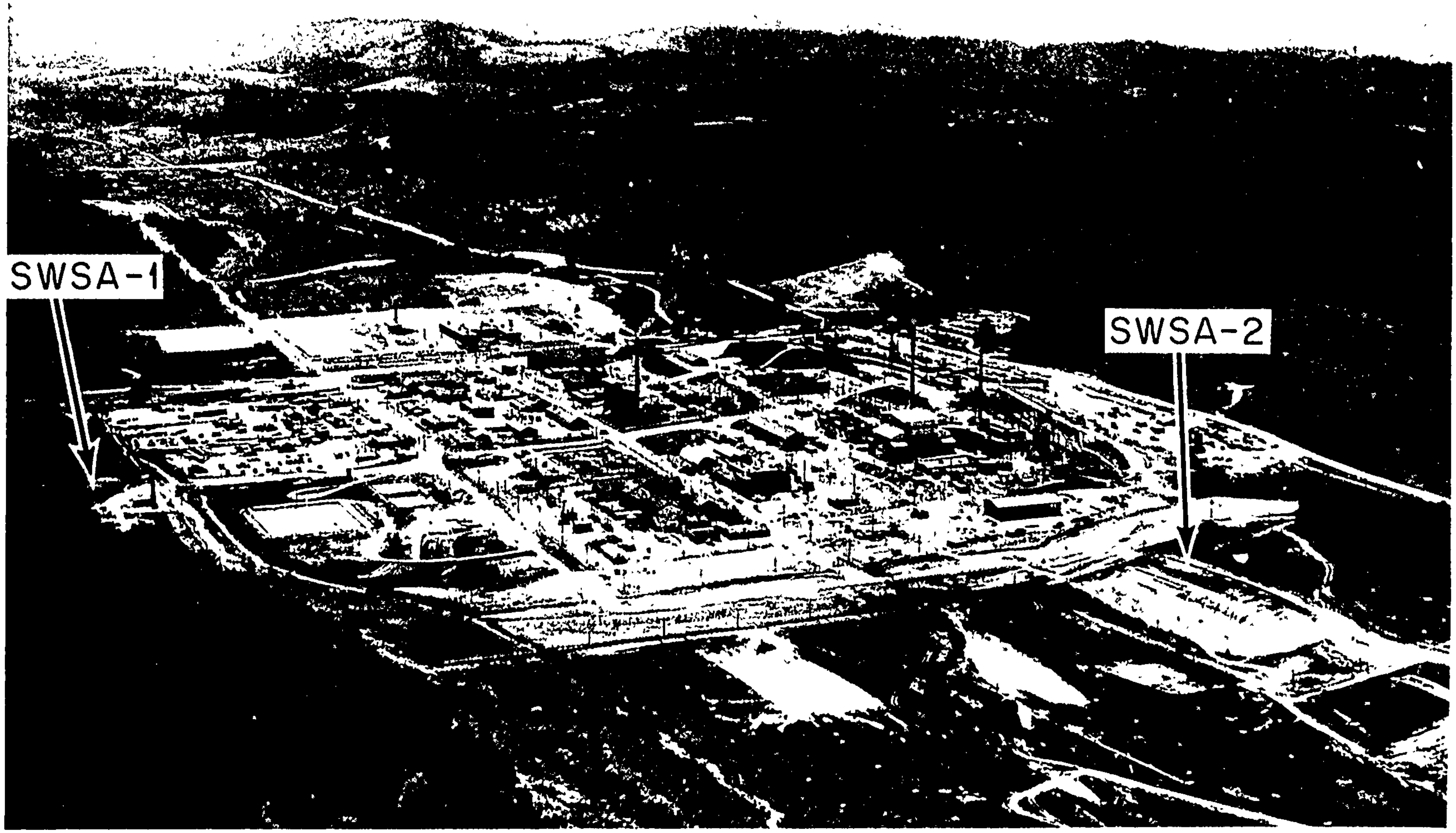


Fig. 21. Clinton Laboratory showing SWSA-1 and 2 (circa 1944).

These areas were used primarily for the disposal of contaminated trash, laboratory equipment, and other items that were discarded. These areas are now completely covered and no longer specifically fenced.

SWSA-3 was opened in 1946 and used for underground disposal of waste, in much the same way as SWSA-1 and -2, until it was closed in 1951. In addition, large items of equipment that were slightly contaminated and either too awkward to bury or salvageable, were stored within the fence around the area. The location of SWSA-3 can be seen in Fig. 19, and in a recent photograph of the area (Fig. 22).

PHOTO 93432

Fig. 22. Solid waste storage area-3 (circa 1971).

After SWSA-3 was opened it was found to be underlain with rock, which made excavation difficult, and it was closed in 1951 after about seven acres had been utilized.

As in the case of SWSA-1 and -2, little information is available on the volume and character of the material buried in this area. Because SWSA-3 is still used for aboveground storage, it is fenced.

B. SWSA-4

By 1951 studies on the movement of radioactive nuclides in soil determined that Conasauga shale was ideal for the burial of radioactive wastes.[4] Consequently, a site for SWSA-4 was chosen in Melton Valley, just southwest of ORNL.

As before, little was done with respect to exploration of the geologic and hydrologic aspects of the site beyond a determination that the area was indeed underlain by Conasauga shale. As a result, portions of the surface of this area are uncomfortably close to the water table. Although the area is no longer in use, a survey to determine what problems, if any, this situation may present is currently being carried on by members of the Environmental Sciences Division. This matter will be addressed in Part II of the review.

Waste storage in SWSA-4 began in 1951 and, as in the previous cases, all disposal was by burial. Attempts were made to segregate beta-gamma and alpha contaminated material; the latter, in some cases, had been covered with concrete prior to back filling. This area (Fig. 20) eventually covered a total of 23 acres; it was closed in 1959, seeded in grass, and fenced. Warning signs indicating the presence of radioactivity are posted in the area.

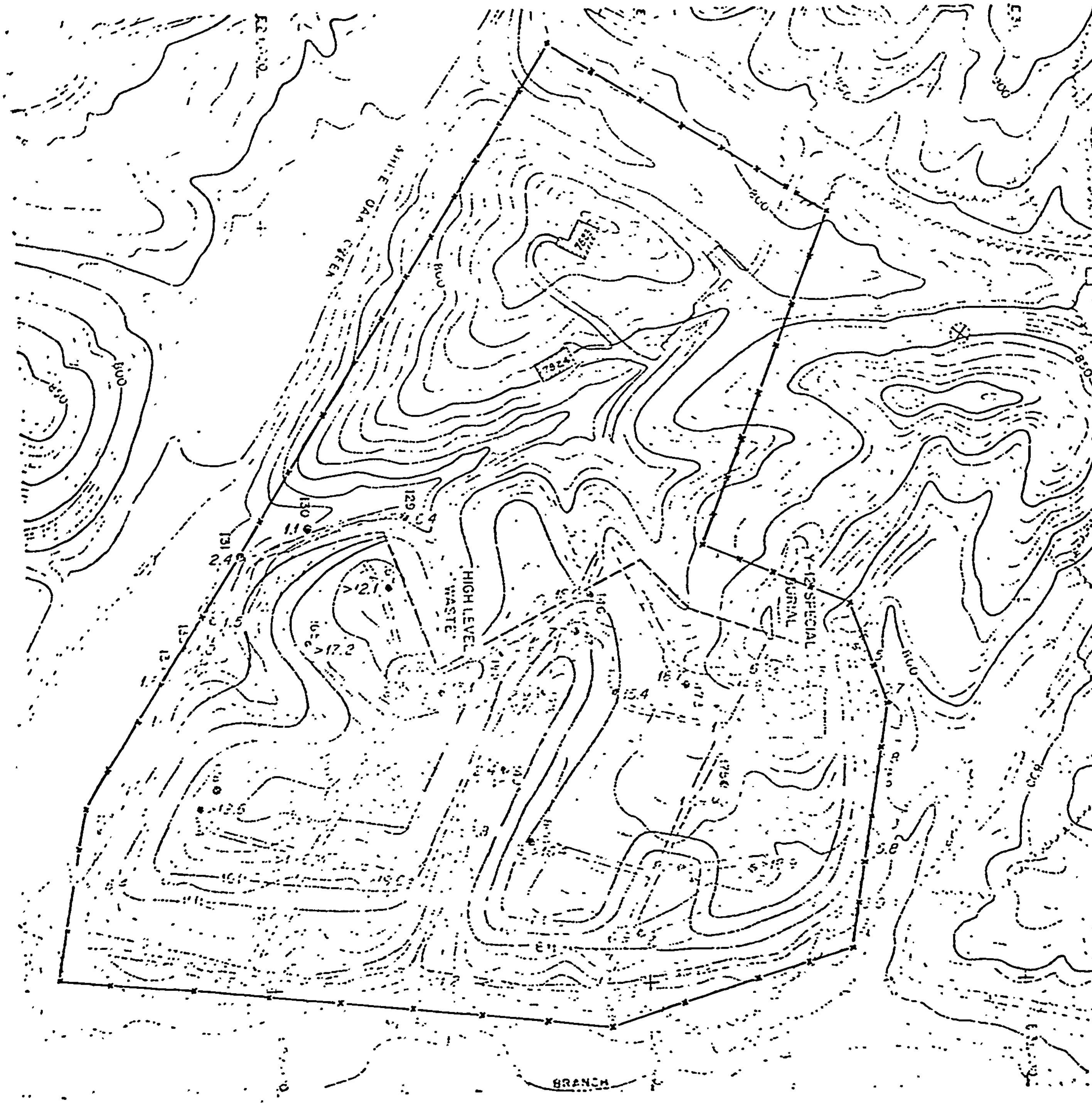
Records were kept of the material disposed of in this area; however, these records were destroyed by a fire in August, 1961, along with part of the records of SWSA-5. Hence, there is no inventory of the material stored in the area.

C. SWSA-5

As a result of experience gained in operating the previous solid waste storage areas, great care was taken in selecting the site for SWSA-5, which was opened in 1959. This previous experience[4] led to the conclusions that (1) a SWSA site should be in an area of gentle relief for ease of operation and yet not be subject to flooding, (2) sufficient depth to groundwater should be maintained so that contaminated solids can be suspended above the water table, and (3) the surface should not be subject to excessive soil erosion by surface runoff. Other desirable features of the site include (1) a soil that is easily excavated by earth-moving equipment and yet firm enough to stand in deep cuts, (2) a short hauling distance from the point of origin of the waste, (3) private roads to use for transporting, and (4) an easily accessible location. A site having the above characteristics and underlain by Conasauga shale would be ideal.

As a result of geographic and hydrographic studies and application of the above criteria, the site shown in Fig. 20 was selected for SWSA-5. Figure 23 is a topographic map of the general area, showing the depth of the water table below the surface.

SWSA-5 has been used for the disposal of all types of wastes described in Section 4; however, by far the largest volume of material is general radioactive waste which has been buried in trenches in "semi-retrievable" form. Nearly all of the "retrievable" material is located in this area, including the material stored aboveground in Building 7823.



LEGEND

⊗ STATE GRID SYSTEM – COORDINATE N 560,000 – E 2,500,000

129 ● OBSERVATION WELL AND NUMBER

15.4 ● DEPTH TO WATER FROM GROUND SURFACE

0 200 400 600 800
SCALE IN FEET

Fig. 23. Topographic map of SWSA-5 show

THIS DRAWING HAS BEEN DEVELOPED FROM A PHOTOGRAPHIC ENLARGEMENT OF A PORTION OF MELTON VALLEY TOPOGRAPHY SHEET I PREPARED BY THE TENNESSEE VALLEY AUTHORITY AUGUST, 1956.

g water table contours.

Land usage of this area since 1961 is indicated in Table 3. The appreciable decline in volume in FY 1963 is caused by the discontinuance of this site as the Southern Regional Storage Area. The trend toward higher waste volumes in FY 1967 and 1968 is considered temporary, and the current projection for the next ten-year period is 200,000 ft^3/year or less.

Table 3. Solid waste storage area-5 — land used and waste volumes

	Land used (acres)	Total volume (ft^3)	Volume generated on-area (ft^3)	Volume received from off-area (ft^3)
1973	0.5	103,047	103,027	20
1972	0.6	122,261	113,026	9,235
1971	0.8	134,319	126,652	7,667
1970	0.8	163,176	157,033	6,143
1969[a]	0.9	169,361	151,210	18,151
1968	2.2	242,079	220,371	21,708
1967	1.1	198,811	170,770	28,041
1966	1.3	159,001	132,606	26,395
1965	1.8	188,534	152,791	35,743
1964	1.5	321,147	121,925	199,222
1963	1.5	332,975	117,470	215,505
1962	2.4	424,650	236,958	187,692
1961	3.0	530,704	244,000	286,704

[a]Changed from fiscal year to calendar year in 1969.

The volume of waste stored per acre is dependent upon terrain features and water table depth. Waste burials in SWSA-5 have varied from 100,000 ft^3 an acre to 220,000 ft^3 an acre. More than 96% of the volume is slightly radioactive material which does not differ from the material buried during the past three decades, and consists of a heterogeneous mass of absorbent paper, all types of glassware, scrap metal, dirt, various filter media, lumber, powder, wire piping, depleted uranium, animal carcasses from biological experiments, and experimental equipment that could not be economically decontaminated.

A general layout of SWSA-5, showing the locations of the various disposal facilities, is given in Figs. 24 and 25. Records of the types of waste and their locations are available for all of the facilities except the trench area shown in the right center of Fig. 25. This area represents that portion of SWSA-5 for which the records were destroyed in the fire mentioned previously.

D. SWSA-6

In anticipation of future needs, the 68-acre SWSA-6 was opened in 1969; its location is shown in Fig. 20. The criteria used to select this site were quite similar to those used in the selection of SWSA-5. Topographical and hydrological maps of SWSA-6 are shown in Figs. 26 and 27.

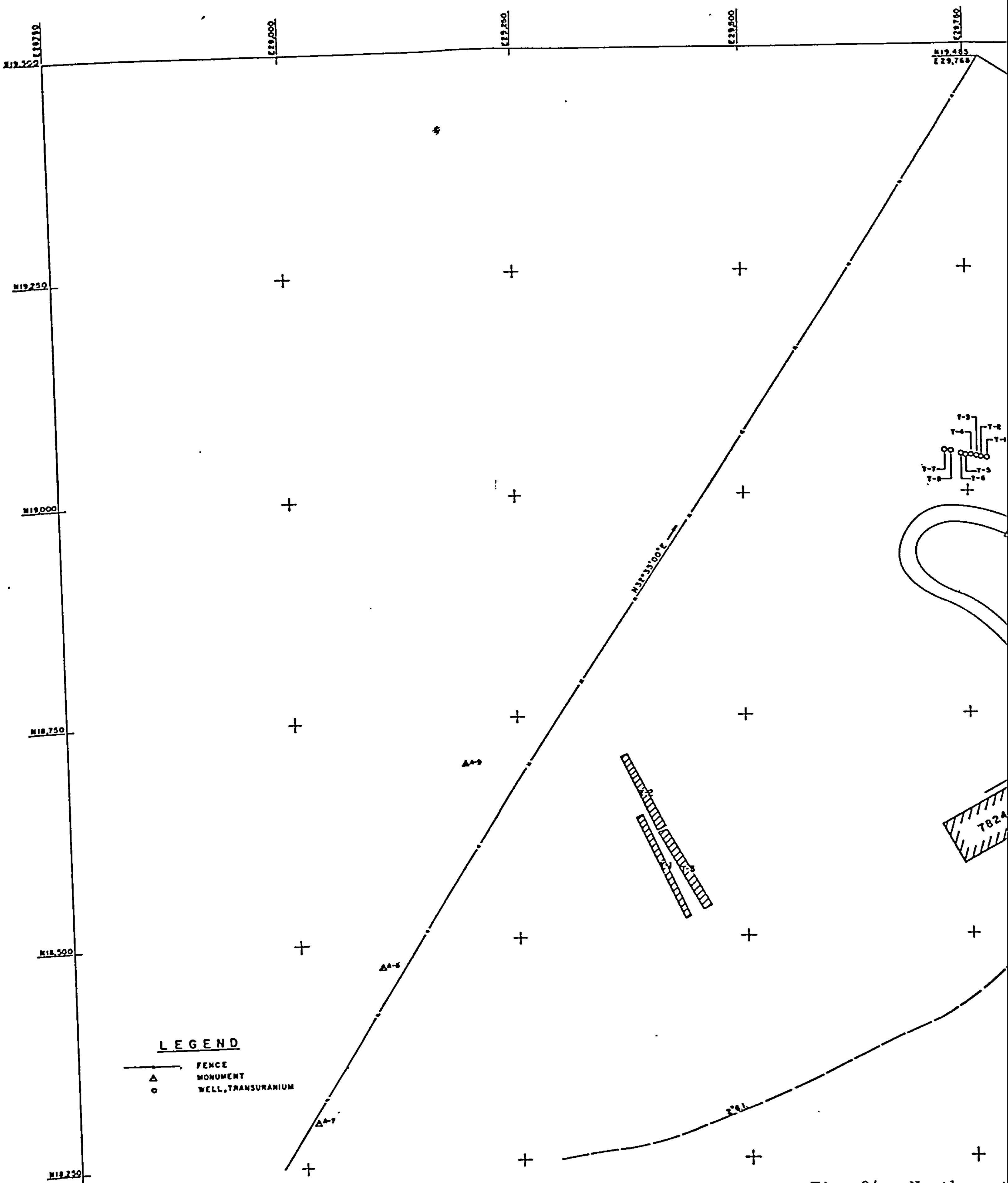
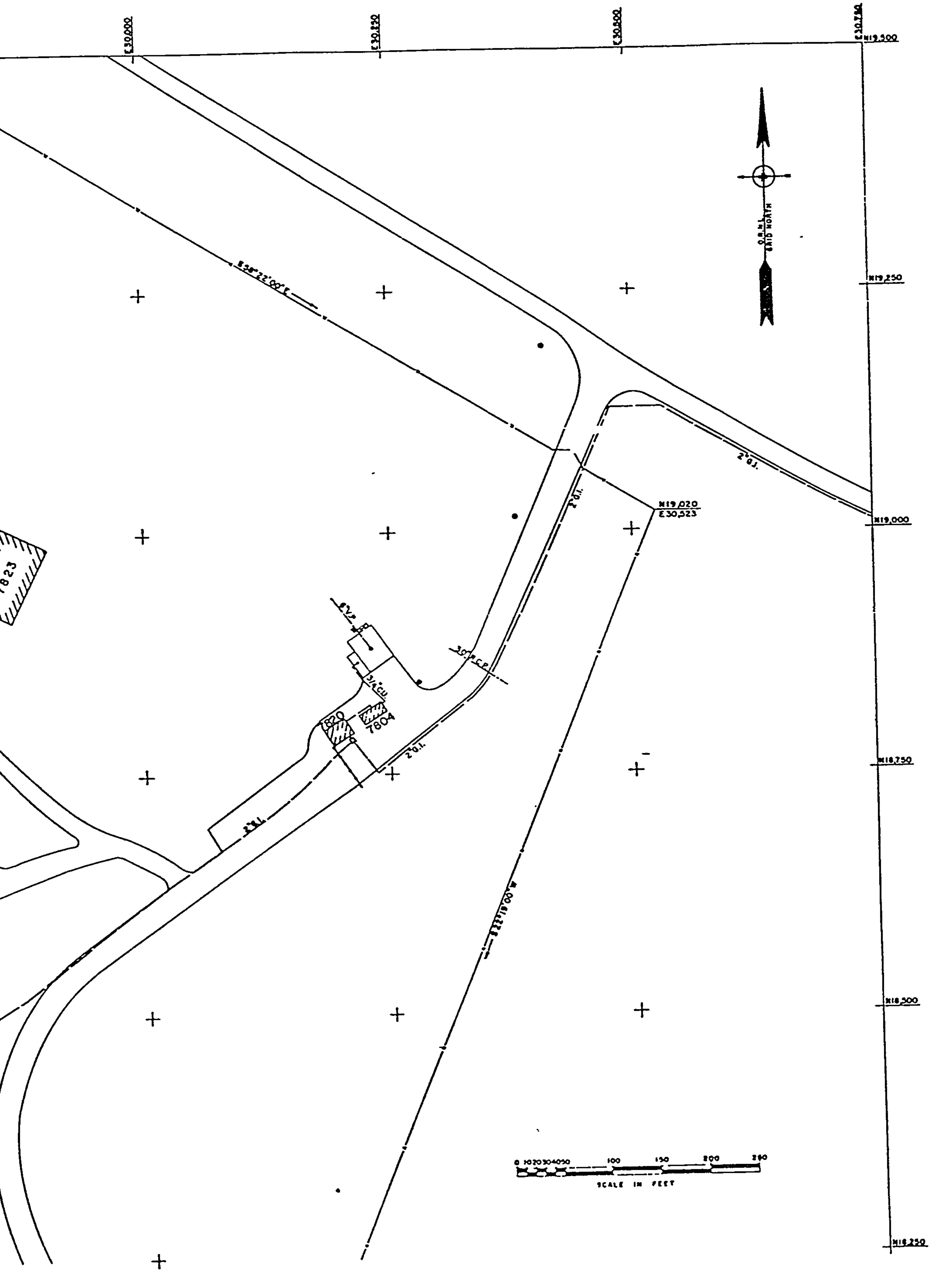
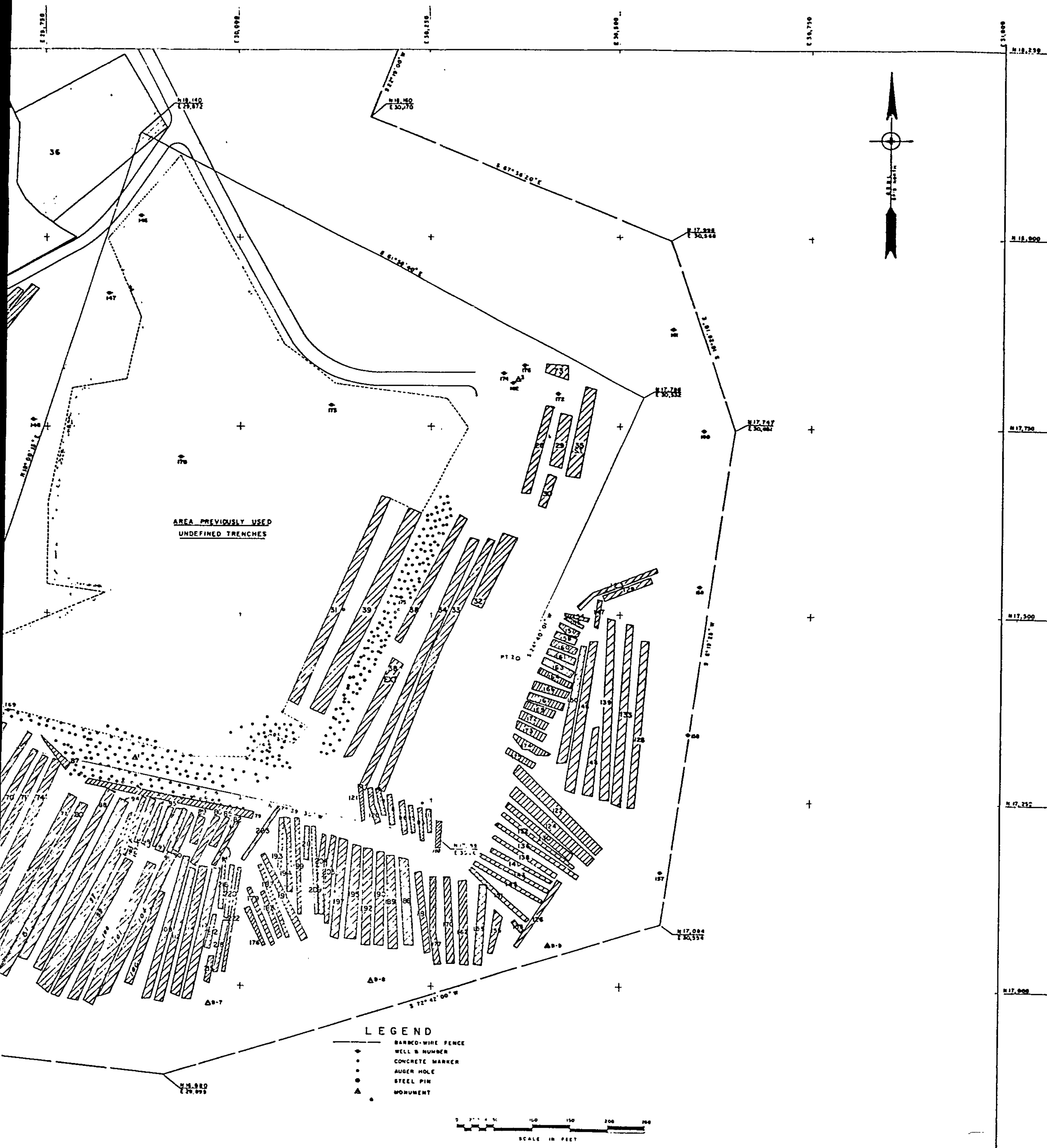


Fig. 24. North port

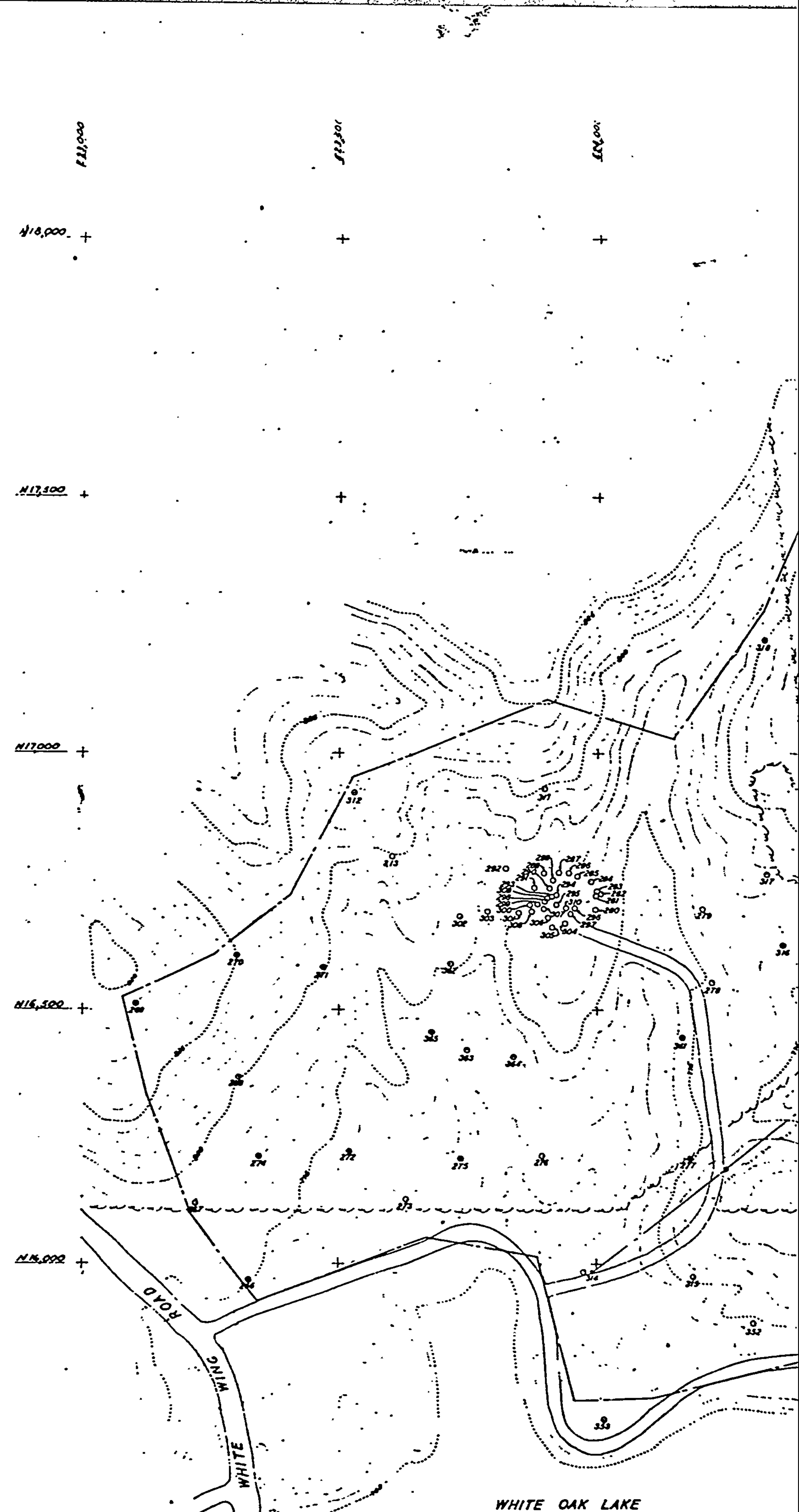

E30,000
E30,250
E30,500
E30,750
N19,500
N19,250
N19,000
N18,750
N18,500
N18,250
N19,020
E30,523
O.R.N.L.
GRID NORTH
2"O.I.
30"R.C.P.
820
7804
7823
SCALE IN FEET

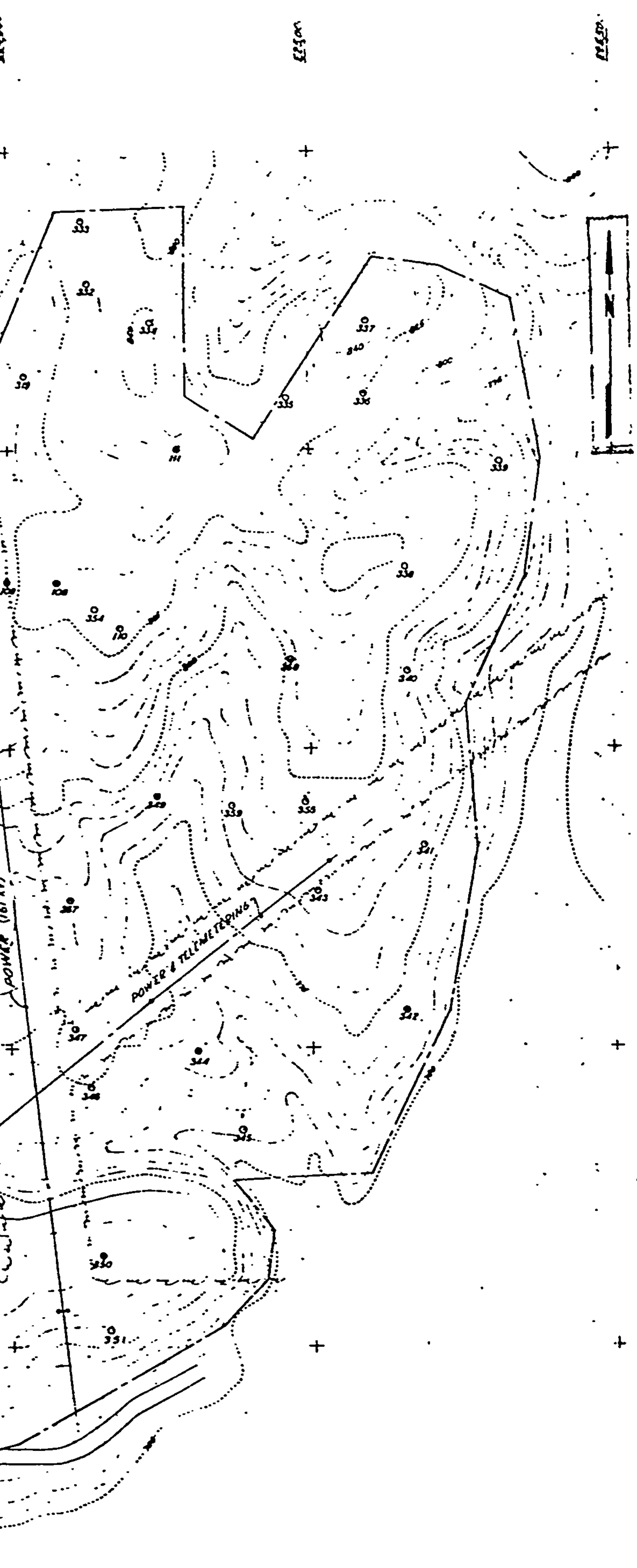
of SWSA-5.

Fig. 25. South portion


AREA PREVIOUSLY USED
UNDEFINED TRENCHES
LEGEND
BARBED-WIRE FENCE
WELL & NUMBER
CONCRETE MARKER
AUGER HOLE
STEEL PIN
MONUMENT
SCALE IN FEET

of SWSA-5.


N18,000
N17,500
N17000
N16,500
N16,000
WHITE WING ROAD
WHITE OAK LAKE



WELL NUMBER	NORTH COORDINATE	EAST COORDINATE	TOP OF CASING ELEVATION
107	17,041.3	24,402.3	813.08
108	17,270.5	24,583.6	832.86
109	17,329.7	24,[illegible]	821.55
110	17,203.5	24,683.9	827.12
266	15,967.8	23,327.4	774.17
267	16,118.2	23,220.8	790.62
268	16,364.7	23,307.3	805.26
269	16,511.2	23,304.2	847.36
270	16,601.5	23,302.5	837.83
271	16,580.7	23,471.5	810.31
272	16,720.7	23,519.9	770.79
273	16,125.5	23,732.9	763 01
274	16,218.3	23,347.1	787.83
275	16,206.2	23,736.8	764.47
276	16,210.7	23,894.8	759.40
277	16,206.7	24,181.5	774 29
278	16,332.4	24,223.1	777.06
279	16,896.2	24,204.9	781.35
280	16,693.6	23,997.0	784.97
281	16,720.4	23,998.1	785 11
282	16,724.7	24,007.6	784.33
283	16,728.9	23,968.9	785.49
284	16,749.6	23,983.3	788 29
285	16,760.6	23,942.2	787 01
286	16,766.5	23,945.0	786.40
287	16,764.5	23,926 7	786.22
288	16,752.1	23,916.0	785.89
289	16,764.9	23,896.3	786.45
290	16,736.9	23,907.1	785.05
291	16,737.8	23,876.7	786.37
292	16,773.4	23,920.9	784.91
293	16,727.8	23,910.6	783.60
294	16,722.3	23,921.0	783.45
295	16,702.7	23,922.0	784.57
296	16,696.9	23,937.7	785.00
297	16,685.2	23,947.0	784.32
298	16,710.6	23,899.3	782.43
299	16,705.3	23,883.1	782.62
300	16,701.9	23,[illegible].2	782.76
301	16,687.4	23,[illegible]7.1	780.01
302	16,679.2	23,734.3	781.10
303	16,609.2	23,781.5	775.61
304	16,646.6	23,934.7	783.91
305	16,640.1	23,913.7	783.76
306	16,678.9	23,904.8	782.86
307	16,694.6	23,897.1	783.60
308	16,890.5	23,872.6	782.28
309	16,715.7	23,903.3	782.73
310	16,696.6	23,939.1	783.99
311	16,936.6	23,900.6	801.39
312	16,922.4	23,529.1	814.53
313	16,798.4	23,604.7	802.78
314	15,985.1	23,977.1	760.80
315	15,976.7	24,187.8	777.61
316	16,626.2	24,361.8	781.62
317	16,765.9	24,328.4	794.75
318	17,225.8	24,373.3	800.06
319	17,625.4	24,529.0	806.43
320 TO 331 – NOT DRILLED			
332	17,780.7	24,636.6	836.57
333	17,866.5	24,626.9	836.19
334	17,715.0	24,737.1	843.23
335	17,588.9	24,964.6	831.63
336	17,594.6	25,091.8	825.66
337	17,717.0	25,095.6	843.62
338	17,305.1	25,157.7	821.12
339	17,680.8	25,316.6	792.52
340	17,130.0	25,160.8	786.37
341	16,836.6	25,185.1	783.72
342	16,561.5	25,154.8	778.96
343	16,762.5	25,010.3	789.80
344	16,494.7	24,810.3	760.33
345	16,360.9	24,801.0	757.26
346	16,634.8	24,630.7	773.09
347	16,538.5	24,606.1	777.36
348 – NOT DRILLED			
349	16,919.6	24,763.4	786.50
350	16,151.6	24,649.0	789.96
351	16,078.4	24,641.2	778.82
352	15,866.7	24,305.1	772.96
353	15,695.1	24,014.5	760.16
354	17,234.5	24,643.9	827.67
355	16,908.5	24,990.7	796.33
356	16,481.2	24,451.3	772.75
357	16,747.2	24,590.5	788.48
358	16,090.6	[illegible]	775.39
359	16,903.5	24,867.2	786.78
360	17,248.0	24,967.8	805.79
361	16,446.2	24,166.1	771.83
362	16,567.6	23,717.6	770.28
363	16,419.6	23,748.1	766.58
364	16,686.6	23,838.2	769.61
365	16,454.4	23,880.5	769.87

CONTOURS APPEARING ON THIS DRAWING WERE DEVELOPED FROM BETHEL VALLEY TOPOGRAPHY SHEET – 1, DRAWING NO. D-26344.

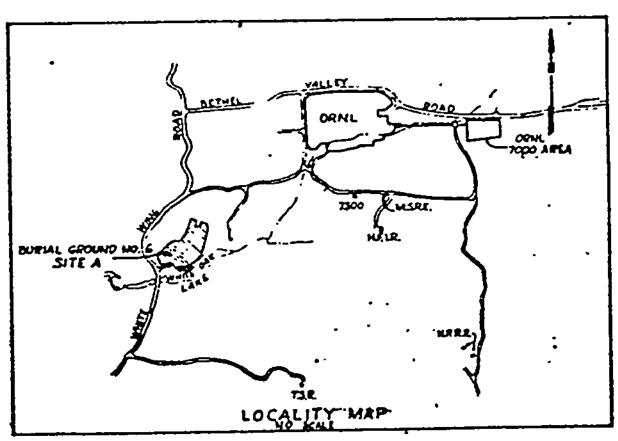
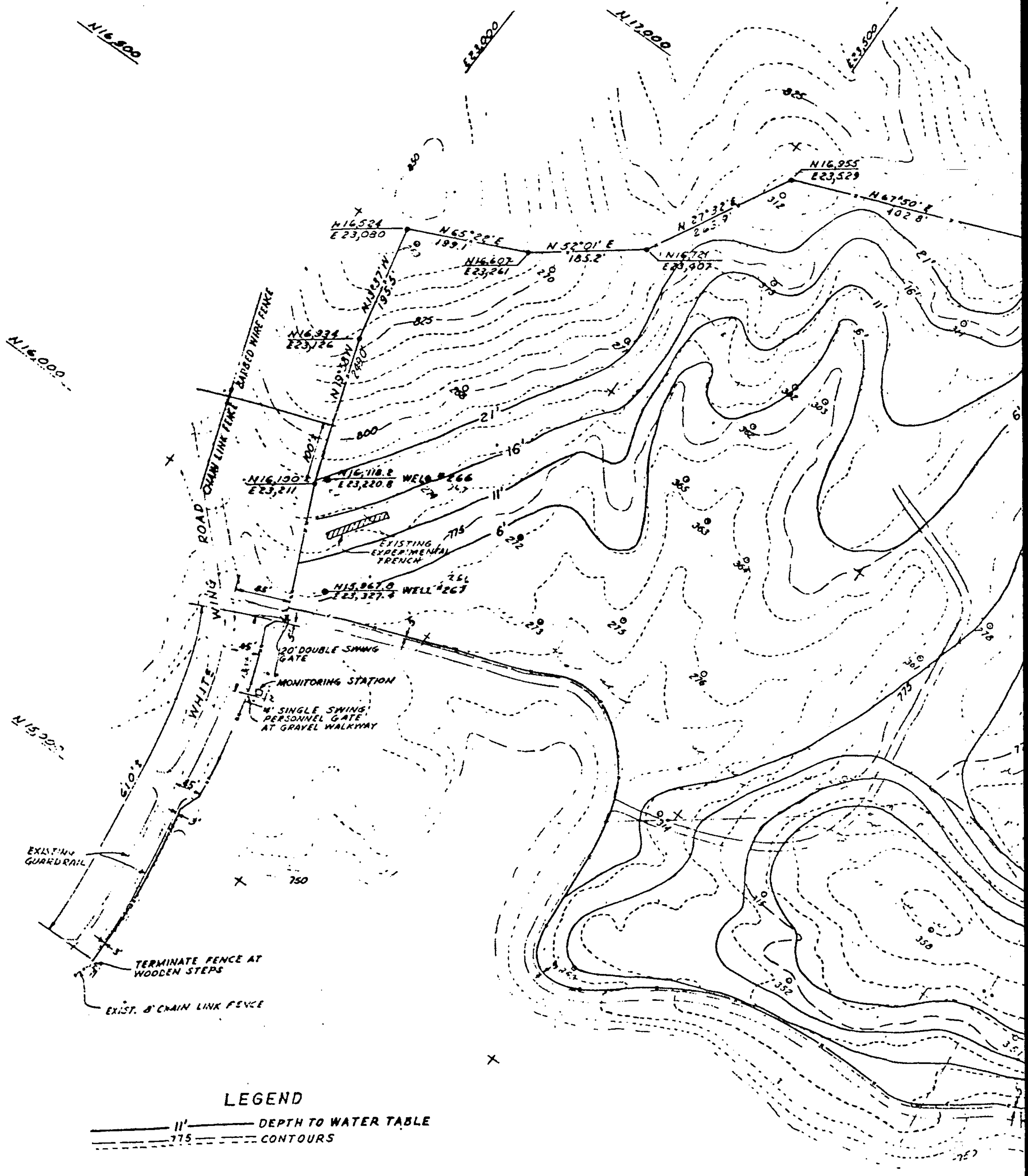


Fig. 26. Topographic map of SWSA-6.



LEGEND

11' DEPTH TO WATER TABLE

775 CONTOURS

Fig. 27. Wate

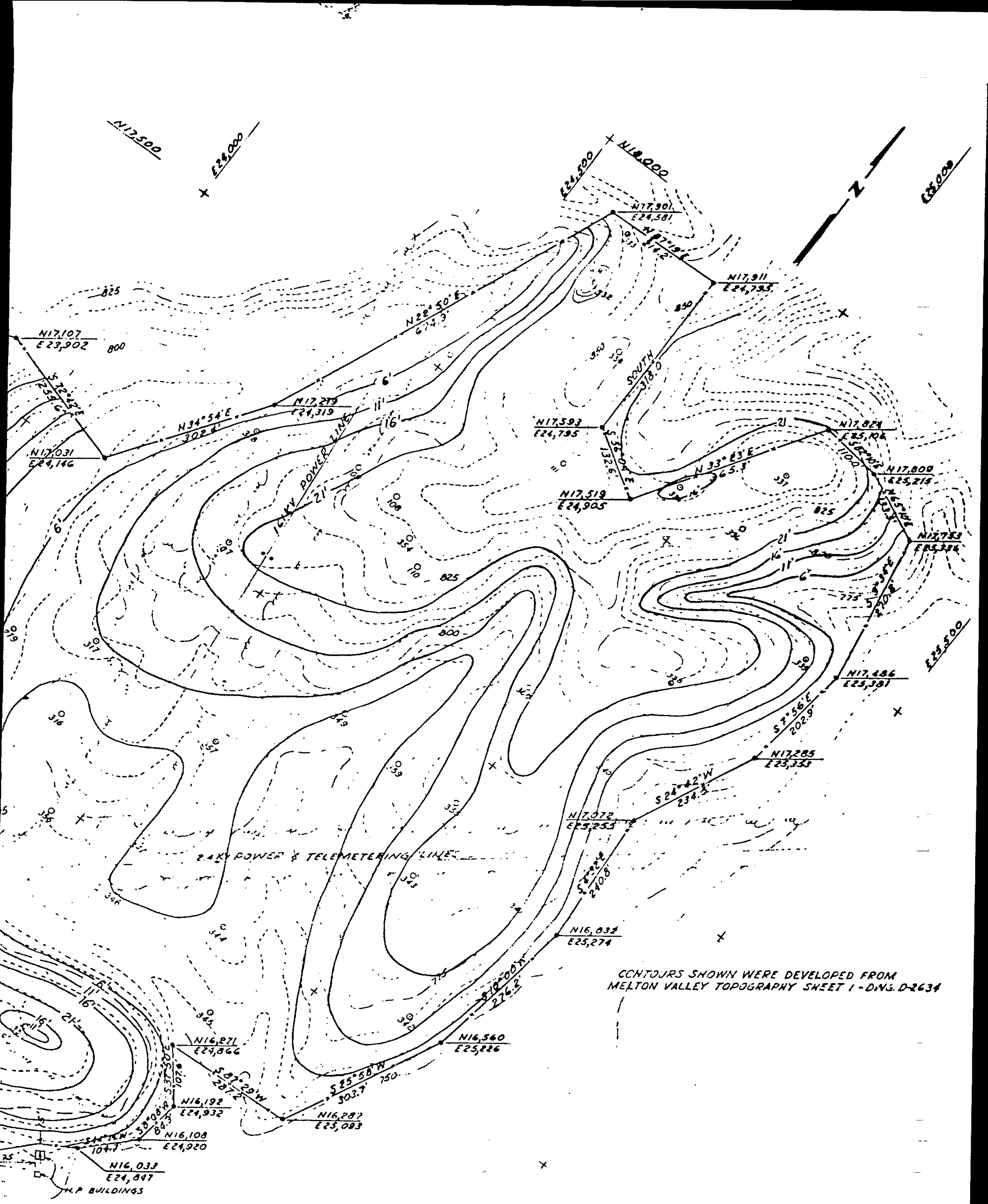


table at SWSA-6.

This area is now being used for semi-retrievable storage in trenches and auger holes following practices identical to those currently in use at SWSA-5. A layout of the facilities in this area is shown in Fig. 28.

6. Procedures for transfer to and handling at the SWSAs

The methods utilized to transport solid waste from its point of origin to the SWSA varies according to the character of the waste and the type of package involved. By far, the greatest volume of waste is handled in dumpsters (Fig. 5) or packaged in cans (Fig. 6), and is transported by a special truck designed to handle the dumpster pan (Fig. 17) or by a truck suitable for transporting cans or drums (Figs. 9 and 29). Handling methods are dictated by normal health physics procedures[1] and are designed to minimize radiation exposure to personnel, to prevent the possibility of contamination, and to meet the principals of industrial safety.

PHOTO 1011-74

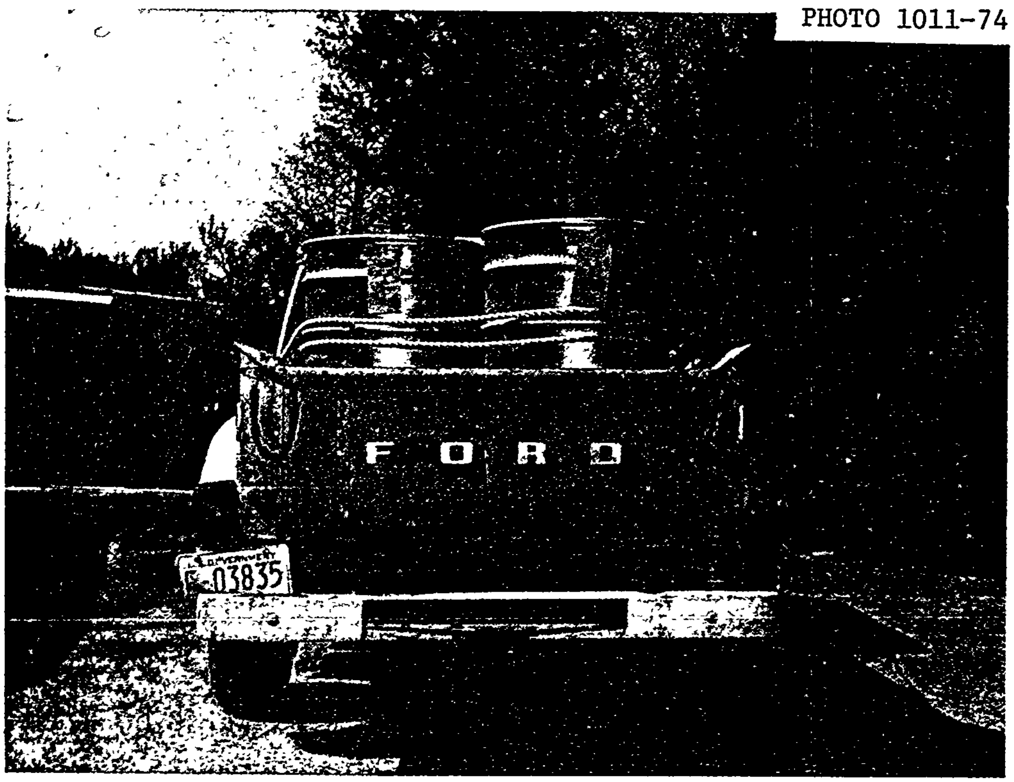


Fig. 29. Truck loaded with waste drums.

In cases where the material involves high radiation or is too bulky or heavy to be handled by ordinary means, special equipment (i.e., mobile cranes, high capacity floats, or shielded equipment) may be used for loading and transportation. In all cases where rigging equipment is

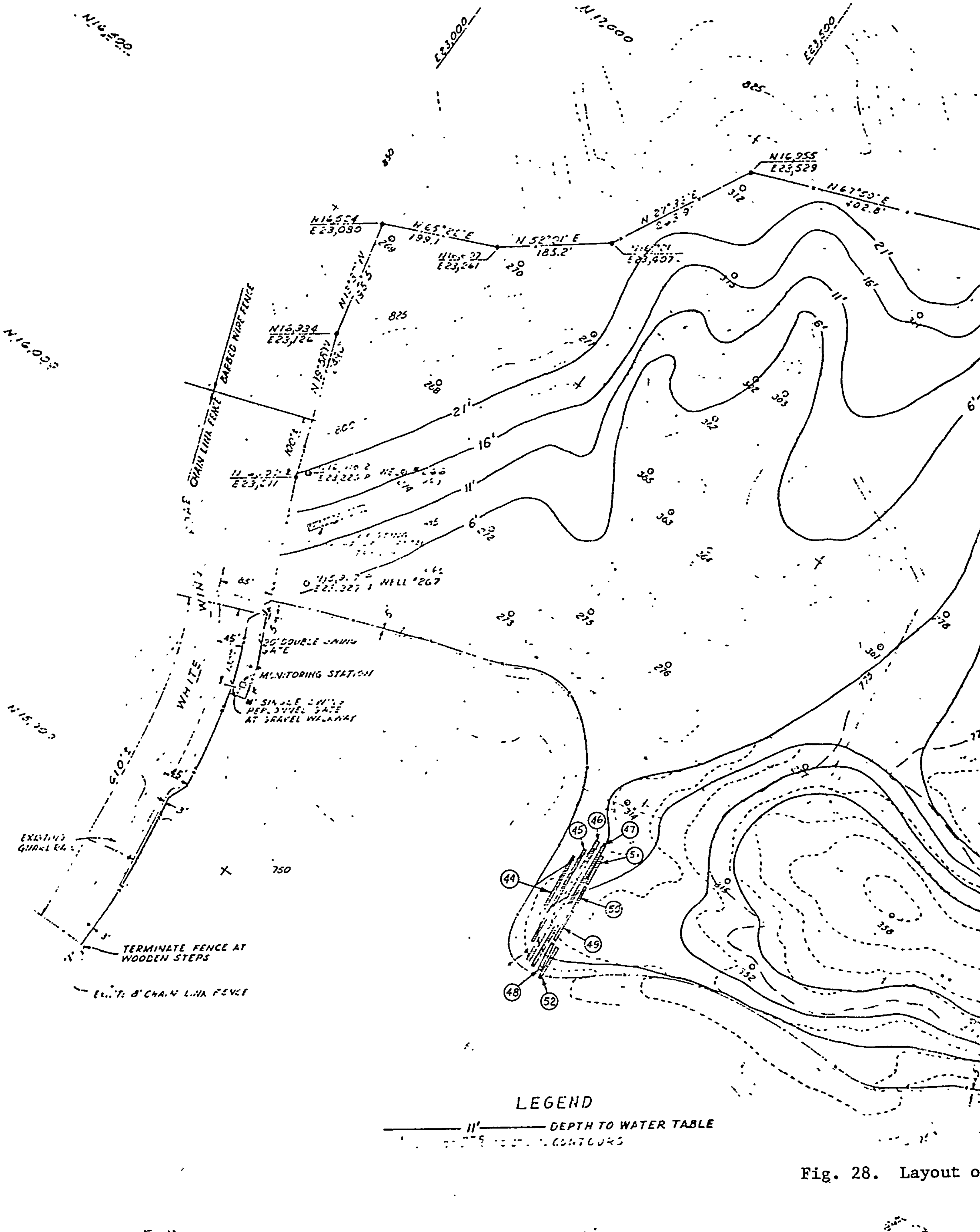
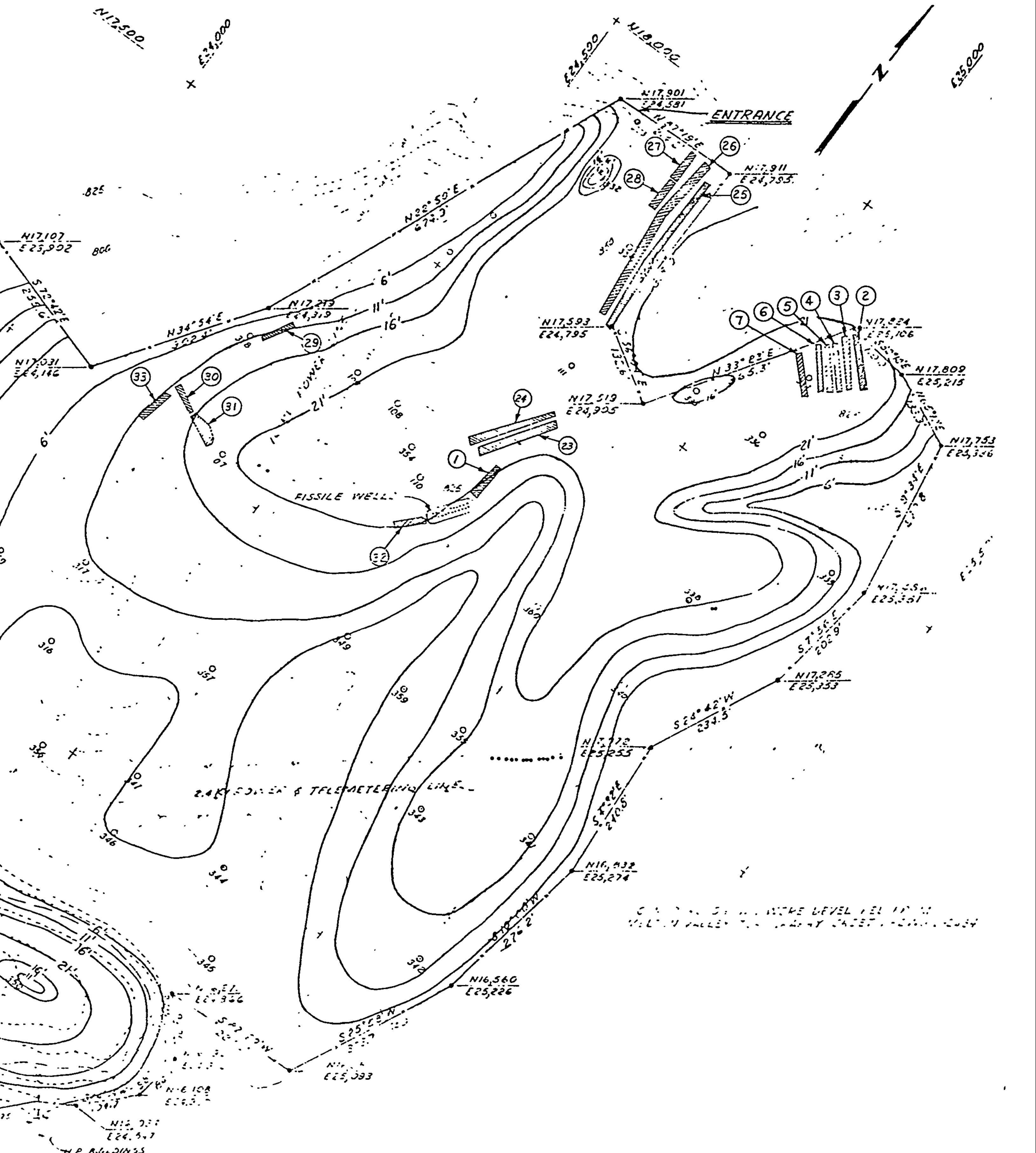


Fig. 28. Layout of



facilities at SWSA-6.

used, the appropriate safety standards for such equipment must be met (Appendix F). Standard procedures are developed for those cases where the heavy shipments are handled frequently.

The movement of the waste from the point of origin to the SWSAs is over roads completely internal to the ORNL reservation, except for those cases where waste is shipped in from offsite. When deemed necessary, special precautions are taken to ensure isolation of the shipment; these could include temporary restrictions on the route, the presence of an escort, or other suitable precautions. Regulations require that all vehicles and equipment used at the SWSAs be surveyed for radiation and contamination and, if necessary, decontaminated prior to leaving the area.

Upon arrival at the SWSA, the waste is stored in an appropriate manner in one of the facilities described in Section 4. The method of handling depends upon the type and physical form of the material.

A. Fissile alpha waste

As is also the case for fissile non-alpha waste, an Authorization for Storage of Radioactive-Contaminated Solid Waste (Fig. 30) and a Record of Transactions of Source and Special Nuclear Materials (Fig. 31) are required by the SWSA foreman prior to accepting the responsibility for these materials. A Request for Nuclear Safety Review (Figs. 32a and 32b) must be processed if the quantities involved exceed those listed in Table 1.

After the necessary paper work has been completed, the containers, properly labeled with a Radiation Hazard Material Transfer Tag (Fig. 33), are picked up on request. The heavier containers such as concrete casks and shielded drums are transported with the aid of rigging equipment (e.g., "floats" and mobile cranes).

As described in Section 3, these materials must be stored in retrievable fashion. Concrete casks are placed in trenches using a crane, and shielded drums and capsules are placed in auger holes in a manner similar to that described in Section 4.

The precautions and dress required for these operations are based on the findings of the area health physics surveyor at the time the Authorization for Storage of Radioactive-Contaminated Solid Waste is prepared. These findings are verified by the field health physics surveyor. In most cases, Company-issued clothing is adequate; however, under some circumstances, contamination zone procedures may be put into effect.

Low level fissile alpha waste is stored in drums and does not require shielding. The drums are shipped by truck and unloaded either by hand or with the help of rigging equipment. They are stacked in Building 7823 with the aid of a forklift truck. Prior to shipment to the SWSA, the outer surfaces of these containers must be decontaminated to such an extent that no special dress precautions other than Company-issued clothing are needed. Criticality restrictions are the same as for non-alpha waste.

AUTHORIZATION FOR STORAGE OF RADIOACTIVE-CONTAMINATED SOLID WASTE

REQUESTER: EXECUTES THIS SECTION BEFORE ARRANGING MATERIAL TRANSFER

MATERIALS TO BE STORED

ISOTOPES PRESENT AND AMOUNT (GRAMS)

ORIGIN - BLDG.	SECTION OF BLDG.	TYPE OF CONTAINER	ATN	SNM

REMARKS

NSR

☐ TRANSURANIUM ☐ FISSILE ☐ NEITHER

TELEPHONE STORAGE AREA FOREMAN PRIOR TO MATERIAL TRANSFER (EXTENSION 3-6356)

REQUESTER'S AUTHORIZATION FOR DISPOSING MATERIALS	NAME		BADGE NO.	BUILDING	PHONE NO.
	DATE	DIVISION	DEPARTMENT		ACCOUNT CHARGE

HEALTH PHYSICS: TO BE COMPLETED AT POINT OF ORIGIN OF SOLID WASTE AND BEFORE TRANSFER OF MATERIAL

RADIATION LEVEL

BETA-GAMMA SHIELDED, mrem@ inches; UNSHIELDED, mrem@ inches.

NEUTRON READING mrem/hr.

SURFACE CONTAMINATION - BETA GAMMA d/minute d/minute Alpha

HEALTH PHYSICIST MUST: ☐ ACCOMPANY SHIPMENT TRANSFER ☐ BE PRESENT DURING STORAGE

REMARKS

HEALTH PHYSICS APPROVAL FOR MATERIAL TRANSFER	NAME	DATE

STORAGE AREA: FOREMAN SENDS COPY TO ORIGINATOR AFTER STORAGE

REMARKS

TRENCH NO.	FFO	FFT	CF
WELL NO.	FFT		CF
BLDG. NO.	COMP. NO.	LEVEL	CF

SUPERVISOR'S RECEIPT OF MATERIALS	NAME	BADGE NO.	DATE	TIME

DISTRIBUTION: WHITE - STORAGE AREA FOREMAN
BLUE - RETURNS COMPLETED TO ORIGINATOR
CANARY - RETAINED BY ORIGINATOR

UCN-2822
(23 2-72)

Fig. 30. Authorization for storage of radioactive-contaminated solid waste (UCN-2822).

OAK RIDGE NATIONAL LABORATORY

RECORD OF SSN TRANSACTIONS

(Intra-ORNL Only)

JEV NUMBER	TRANSFER NO.
	SNM – 239

FROM:				TO:			
1 BALANCE AREA	2 CONTROL AREA	3 MATERIAL STATUS	4 DATE	1 BALANCE AREA	2 CONTROL AREA	3 MATERIAL STATUS	4 DATE
5 PROJECT NUMBER		6 TYPE TRANSACTION		5 PROJECT NUMBER		6 TYPE TRANSACTION	

7 SIGNATURES	7 SIGNATURES
SENDER	RECEIVER
BALANCE AREA REPRESENTATIVE	BALANCE AREA REPRESENTATIVE

WEIGHTS IN GRAMS

		COLUMN NUMBER	1	2	3	4
10 Nuclear Material Code	11 Wt. % Isotope	8 Item No.				
		9 Chemical or Physical Form				
		12. Element Weight				
		Isotope Weight				
		Element Weight				
		Isotope Weight				
		Element Weight				
		Isotope Weight				
		Element Weight				
		Isotope Weight				
		Element Weight				
		Isotope Weight				
13. Estimated Limit of Uncertainty per Column		Element(s)				
		Isotope(s)				
14. Number of Pieces						
15. Container Number						
16. NSR Assigned to Container or Transfer						
17. Analytical Report Number						
18. Assay Report Number						
19. Gross Weight of Container and Material - Lbs						
20. Net Weight of Material - Grams or Volume						

NOTE: SHIPPER-RECEIVER DIFFERENCES MUST BE REPORTED TO SS OFFICE IMMEDIATELY FOR RECONCILIATION

OTHER PERTINENT COMMENTS

DISTRIBUTION: (White) Accountability Office - (Canary) Receiver - (Blue) Shipper

UCN 2681
(3 7 72)

Fig. 31. ORNL record of SSN transactions (UCN-2681).

REQUEST FOR NUCLEAR SAFETY REVIEW

This request covers operations with fissile material in a control area and/or fissile material transfers that originate within the control area. The control area supervisor shall complete the blocks below and describe the process and/or operations to be performed, emphasizing the provisions for nuclear criticality safety on the reverse side of this page. This request shall be approved by the Radiation Control Officers of the originating Division and the Division(s) to which fissile material will be transferred.

EXPIRATION DATE

TITLE, CONTROL AREA, AND SUMMARY OF BASIC CONTROL PARAMETERS

(To be completed by the Control Area Supervisor)

TITLE (FOR REFERENCE PURPOSES)			DATE OF REQUEST	DATE REVIEW REQUIRED
CONTROL AREA	CODE NO.	BUILDING ROOM	DIVISION	

TYPE AND FORM OF MATERIAL		
ISOTOPIC ENRICHMENT (Wt. %)		
QUANTITY OF FISSILE ISOTOPES	PER ISOLATED BATCH OR UNIT	
	TOTAL IN CONTROL AREA	
	TOTAL TO BE PROCESSED	
Concentration or Density of Fissile Material		
Spacing of Fissile Units		
Proximity and Type of Neutron Reflectors or Adjacent Fissile Material		
Limit on Moderation		
Limit on Neutron Absorbers		
Limit on Volume or Dimensions of Containers		

THIS REQUEST (MODIFIES, REPLACES) NSR(S) NO.

RECOMMENDATIONS

(To be completed by the Criticality Committee)

This endorsement is based on our present understanding of the operation (whether acquired verbally or in writing) and is subject to review and cancellation.

CHAIRMAN, CRITICALITY COMMITTEE DATE

UCN-5917
(3 9-70)

Fig. 32a. Request for nuclear safety review (UCN-5917).

PROVISIONS FOR NUCLEAR CRITICALITY SAFETY
(To be completed by the Control Area Supervisor)

Provisions for nuclear criticality safety shall be described below in accordance with Appendices II and III of the AEC Manual Chapter 0530. This shall include brief descriptions of the process and/or all operations to be performed, plans and procedures for the operations for nuclear criticality safety, and the basic control parameters. Please attach 11 copies of referenced drawings and documents.

EXPIRATION DATE

RADIATION CONTROL OFFICER	DIVISION	CONTROL AREA SUPERVISOR	BUILDING
RADIATION CONTROL OFFICER	DIVISION	RADIATION CONTROL OFFICER	DIVISION

Fig. 32b. Request for nuclear safety review (UCN-5917).

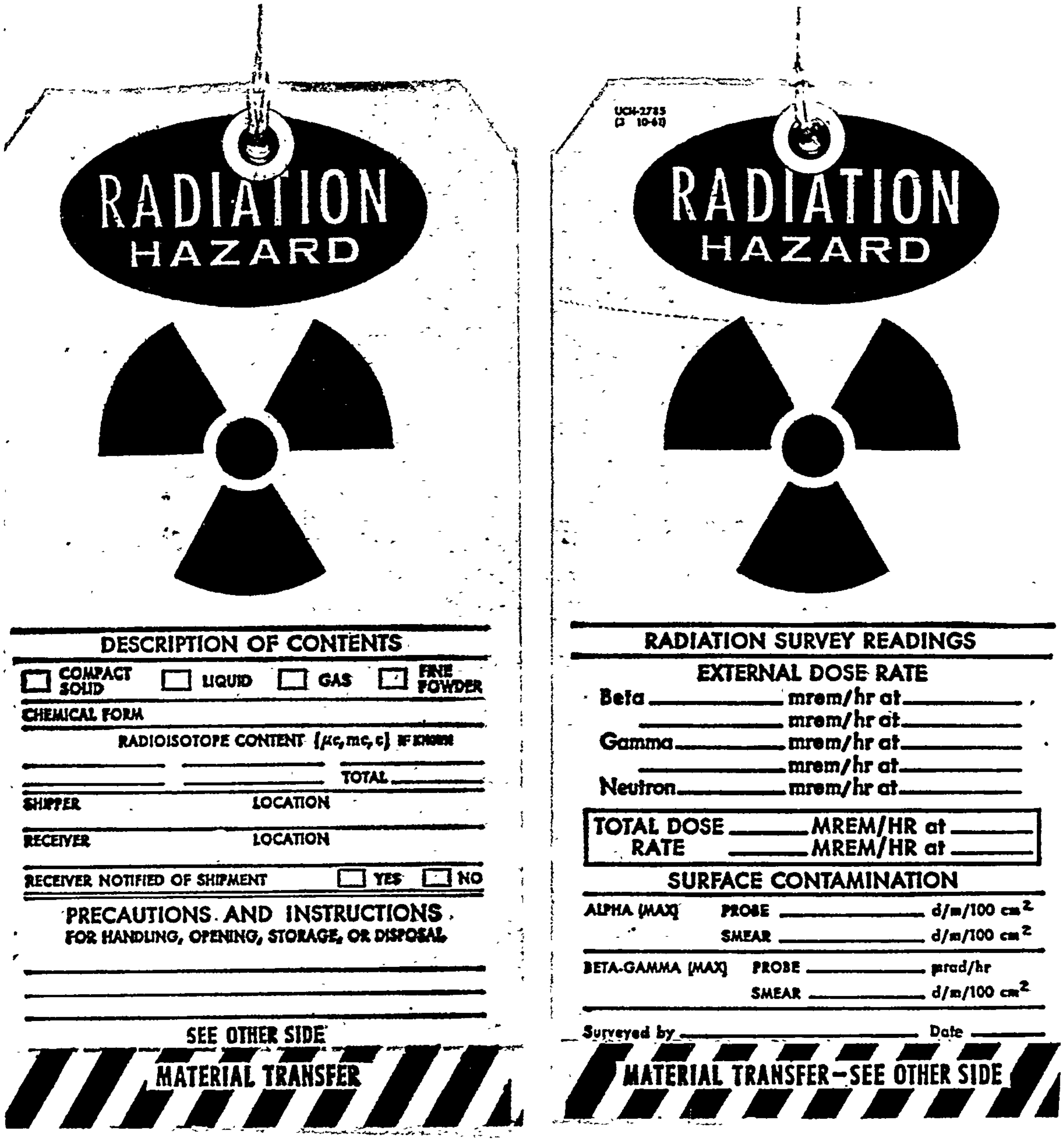


Fig. 33. Radiation hazard material transfer tag (UCN-2785).

B. Fissile non-alpha waste

Fissile non-alpha waste is collected from the originator upon request. Prior to transferring responsibility for this waste to the SWSA foreman, the originator must prepare an Authorization for Storage of Radioactive-Contaminated Solid Waste, describing the material and any special precautions required. In addition, a Record of Transactions of Source and Special Nuclear Materials must be completed. This document is used primarily for accountability purposes, but it also specifies the type and quantity of material involved. In cases where the amount of fissionable material in a container exceeds that specified in Table 1, the originator is required to submit a Request for Nuclear Safety Review (Figs. 32a and 32b) to the ORNL Criticality Committee (Part I, Section 7). This request is reviewed by the Committee, and disposal of the material must be handled in accordance with the recommendations of the Committee.

Unpackaged bulk material containing less than 1 g/ft^3 of fissionable isotopes may be stored in a semi-retrievable fashion without ORNL Criticality Committee approval.

Fissile non-alpha waste is packaged in suitable containers and surveyed by a health physics surveyor who affixes a properly completed Radiation Hazard Material Transfer Tag to the container. The package, in a shielded or unshielded condition, is then conveyed to the SWSA where it is placed in an auger hole. When a shielded container is used, mobile lifting equipment is necessary; otherwise, the container may be moved by hand and transported by truck.

Company-issued clothing is used for this operation, and radiation monitoring, if necessary, is handled by health physics personnel. Shielded containers may be either top- or bottom-loading and, if required, temporary means are devised to shield personnel during the transfer of material from container to the auger hole.

C. General radwaste

Low and intermediate level general radwastes are routinely removed from the point of origin in dumpsters or in metal waste cans as described in Section 3. Service is provided primarily on an "on-call" basis. The material is packaged by the originator and, when ready for shipment, surveyed by a member of the Radiation Safety and Surveys Section to determine if the material indeed is low or intermediate level general radwastes. A Radiation Hazard Material Transfer Tag (Fig. 33) is affixed, which describes the contents and the results of the survey. The waste is then picked up and transported to the SWSA where it is emptied into a disposal trench without being reopened (Fig. 15).

Radiation monitoring in this case is routine and is guided by the original survey. Company-issued clothing is worn by the crew, and all are required to wear film badges, personal dosimeters, and pocket meters. The pocket meters are read daily by personnel of the Radiation Monitoring Section of the Health Physics Division.

High level general radwaste with a surface radiation level in excess of 200 mR/hr and certain other hazardous types of material such as NaK are also removed from the point of origin on an "on-call" basis. Shipment and storage of materials of this type are treated individually by procedures appropriate for the particular situation involved.

Each container is loaded by the originator and surveyed by health physics personnel; as in the previous case, a Radiation Hazard Material Transfer Tag (Fig. 33) is affixed. In addition, the originator and the area health physics surveyor are required to complete an Authorization for Storage of Radioactive Contaminated Solid Waste (Fig. 30). This form contains a description of the material and specifies the precautions to be taken during handling and storage. The SWSA foreman reviews this form prior to accepting the material and, together with the field health physics surveyor, determines the proper handling procedure. After making the necessary preparations, the foreman approves the transfer. This type of waste is placed either in a trench or auger hole.

If transported in lead-lined Dumpster pans, the waste is emptied into a trench using a motor crane. Usually, several pans are emptied at one time. Pans being held at the SWSA for emptying are stored under a sheet-metal rain shield.

Shielded carriers of high level radioactive waste are transported by truck or yard crane and unloaded, using mobile lifting equipment. Top-loading carriers are used as infrequently as possible, but, if used, they are lowered into the trench, using a crane, and then inverted to empty the contents. Some bottom-loading carriers are suspended in the trench and emptied.

Some high level waste is received in 55-gal drums transported in a shielded carrier. The drums are lowered by means of a mobile crane through the bottom part of the carrier after it has been placed over an auger hole. In most cases, the likelihood of contamination is sufficiently low that only Company-issued work clothing is required for this operation.

After emptying, carriers are reassembled as required, wiped externally, and surveyed by a health physics surveyor before being wrapped in plastic and returned to the owner.

Bulk shipments of high level general radioactive waste, such as contaminated earth or construction debris, are usually received in a dump truck or on a float. Where possible, the material is placed in the trenches using a crane; otherwise, it is merely dumped. A health physics surveyor is in attendance during these operations and assists the foreman in determining the degree to which personnel are required to dress out in contamination zone clothing and to observe precautions prescribed for contamination zone operations.[1] Moreover, these dumping operations are carried out only under appropriate meteorological conditions (e.g., low wind speed).

Shipments of radioactive waste materials, which must be regarded as non-routine for reasons other than high level radiation, are handled on a case-by-case basis in accordance with procedures developed by the SWSA foreman after consultation with the health physics surveyor, his Division Radiation Safety and Control Officer, and, if deemed necessary, his supervision.

7. Organization

The responsibility for the operation and maintenance of the facilities for the disposal and storage of solid radioactive waste at the Oak Ridge National Laboratory was assumed by the Operations Division in July 1973. Direct responsibility is vested in the Hot Cells and Solid Waste Storage Operations Department, with technical staff assistance being available from the Development and Technical Assistance Departments of that Division.

Close liaison is maintained with the Radiation and Safety Surveys Section of the Health Physics Division and with the Plant and Equipment Division. The former provides health physics surveillance for the operation, and the latter supplies craft personnel, heavy equipment operators, truck drivers, laborers, etc., who perform much of the actual work.

A chart showing the organization of the solid waste storage operations is shown in Fig. 34.

In addition to the direct supervision provided by the Operations Division, the solid waste storage operations is under the surveillance of the Division Safety and Radiation Control Officer and three of the Laboratory Director's Review Committees.

A. Criticality Committee

The Criticality Committee has review and approval jurisdiction over operations that involve the handling, storage, transportation, and disposal of significant quantities of fissile material. The fissile materials include the isotopes ^{235}U, ^{233}U, ^{239}Pu and the combined elements americium and curium. Approval for operations involving masses of the above materials in excess of the waste disposal limits must be obtained in advance on a nuclear safety review form submitted to the Committee. This form is initiated by the requester of the operation, approved by his Division Safety and Radiation Control Officer, and finally approved for a limited period of time by the Committee.

Disposal of fissile material must be in accordance with the procedures in the ORNL Health Physics Manual[1] with the approval of the Committee.

The Committee acts in many respects as a consulting group and gives assistance in problems involving criticality. It also conducts an annual review of each facility or balance area possessing significant amounts of fissile material to ensure that approved procedures are being followed.

ORNL-DWG 74-8150

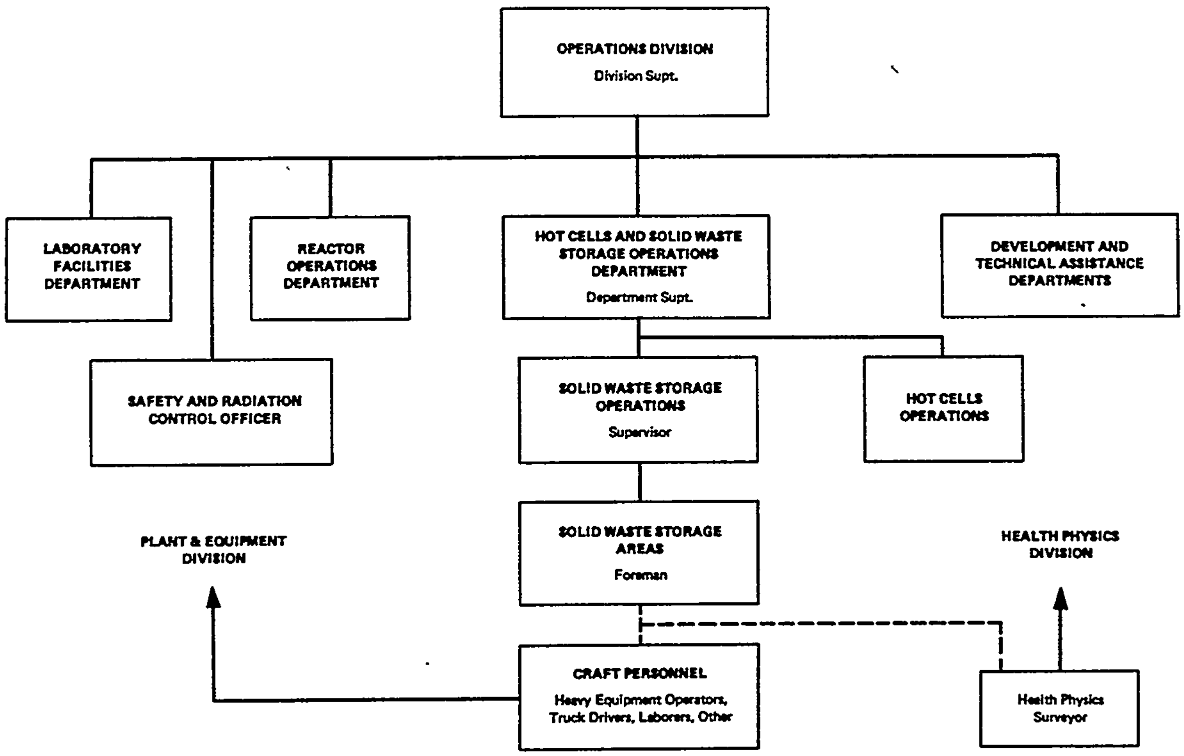


Fig. 34. Organization chart for Hot Cells and Solid Waste Storage Operations.

B. Radioactive Operations Committee

The Radioactive Operations Committee reviews Laboratory facilities handling or processing significant quantities of radioactive materials and the practices used in disposal of solid, liquid, and gaseous radioactive waste. The Committee is particularly concerned with proper containment, complete and accurate operators' safety analyses, detailed operating procedures, and possible interactions (chemical, mechanical, or procedural) that might lead to unplanned exposure or contamination.

All new radiochemical facilities or processes are reviewed prior to operation; existing facilities are reviewed whenever changes in purpose or scope are proposed. The more important facilities are reviewed by the full Committee at intervals of one to three years, even though no changes in purpose or scope have been made or requested. Frequency is dependent on the magnitude of the operation and the hazard involved.

C. Transportation Committee

The Transportation Committee is an ORNL standing committee appointed by and reporting to the Director. Serving on the Committee are specialists in the fields of stress analysis, inspection techniques, shielding, heat transfer, criticality, and transportation regulations. The Committee, on its own initiative or at the request of ORNL management, reviews all safety aspects of any phase of operations involved in the transfer of radioactive or fissile materials from one ORNL facility to another or one ORNL group to another, as well as shipments made offsite from ORNL. The Committee reviews casks used for intra-Laboratory transportation, and also such details of shipments as tie-down practices, vehicles used for transport of casks, inspection procedures, loading and unloading procedures, and any other procedures necessary for the safe transportation of radioactive materials.

The Committee also reviews accidents or incidents involving transportation of radioactive materials when they feel such reviews might produce useful information.

The conclusions and recommendations are summarized in reports to the Laboratory Director and to the appropriate Laboratory Division concerned.

PART II. SAFETY ANALYSIS

PART II. SAFETY ANALYSIS

1. Introduction

The policy of the Oak Ridge National Laboratory is to conduct its operations in a fashion that will ensure the control of all potentially harmful effects to persons, to the environment, and to facilities and equipment. The operations associated with the storage of solid waste are carried out in accordance with this policy.

The potential hazards that accompany these operations fall into two general categories: hazards to the personnel engaged in the operations, hereinafter called "operational hazards;" and potential hazards to the general public, which for convenience are designated as "environmental hazards." Operational hazards include the ordinary industrial safety hazards that accompany any excavation, hauling, or lifting operation and also contamination, radiation, and criticality hazards that may arise because of the peculiar nature of the material being handled. Environmental hazards are due almost exclusively to the radioactive or fissile nature of the waste, but in rare instances, could be caused by ground burial of nonradioactive chemical wastes. In nearly all cases, the wastes are "passive" in the sense that the toxic material stored does not possess a high potential for rapid energy release. This fact constitutes an important distinction between the hazards associated with a chemical reprocessing plant or a nuclear reactor and those associated with radioactive waste storage.

In this review the contamination, radiation, and criticality hazards, in particular those with an environmental connotation, are of most concern. However, the ordinary day-to-day operational hazards are most likely to result in real injury, and for completeness, some attention will be directed to these problems.

2. ORNL radiation protection and safety policy

A. Radiation protection policy

The radiation safety policy of the Oak Ridge National Laboratory is specifically set forth in Section 1.1 of the ORNL Health Physics Manual.[1] This policy requires that all operations be conducted in a manner which ensures that radiation exposures to personnel will be maintained at a reasonably low level and will in no case exceed the standards established by the U.S. Atomic Energy Commission; and that every effort will be made to perform the work in such a way that losses of material and equipment as a result of contamination will be minimized. Moreover, environmental contamination must be maintained at as low a level as possible, consistent with sound operating practice. In no case should environmental contamination outside the controlled area be permitted to exceed the maximum permissible concentration values applicable to individuals residing in uncontrolled areas.[5]

B. Safety policy

As stated in the Introduction, the policy of the Oak Ridge National Laboratory is to conduct its operations in a way that will ensure the control of all potentially harmful effects to persons, to the environment, and to facilities and equipment. The specific objectives of the ORNL safety policy are contained in a document entitled, "The Safety Program of the Oak Ridge National Laboratory,"[6] and are designed to fully satisfy the safety requirements of AEC Manual Chapter 0550 (Appendix G). The ORNL safety policy includes the requirements that all activities be conducted with the lowest reasonable risk of personal injury or property loss, that all work be performed in accordance with Laboratory safety regulations and designated national codes and standards, and that all significant accidents be investigated to determine their cause and to prevent their recurrence.

C. Implementation

(1) Operational safety

Implementation of these policies is regarded at ORNL as a line organization function, and direct responsibility for the operational safety of the solid waste storage activities rests with the supervision and personnel of the Operations Division. The division safety officer represetns the division in matters of safety and at the division level, discharges the responsibilities designated by the division director. Members of the Health Physics and Safety Section of the Health Physics Division are responsible for auditing Laboratory safety practice, and are available to advise the Operations Division on the safe conduct of its work. The Manager for Laboratory and Personnel Protection represents the Laboratory Director in all safety matters; and with the aid of the Radioactive Operations Committee, the Criticality Committee, and the Transportation Committee conducts periodic audits and reviews of the procedures and practices utilized by solid waste storage operations.

(2) Environmental safety

Although protection against environmental hazards is also basically a line organization function, the implementation of environmental safety precautions is treated in a Laboratory-wide manner because of the complex nature of the problem. Appropriate procedures and guidelines have been developed to ensure that all of the Laboratory operations remain well within the limits set forth in AEC Manual Chapter 0524, Standards for Radiation Protection (Appendix H).

In order to ensure that solid waste storage operations are carried out in a manner consistent with these limits, the procedures and practices are reviewed and audited by the Safety and Radiation Control Department, the Committees named above, and, in some cases, the Health Physics Division, the Environmental Sciences Division, or by special groups convened to examine particular problems.

Offsite monitoring for the presence of radioactive materials is carried out by the ORNL Health Physics Division[7] with the assistance of the ORNL Environmental Sciences Division[8] which also carries out special studies to determine the effects of radioactive effluents on the local environment. Routine onsite monitoring is handled by the Laboratory Facilities Department of the Operations Division.

3. Operational hazards

A. Radioactive

(1) Radiation and contamination hazards

Radiation hazards to personnel engaged in the disposal of solid wastes are generally of two types: direct radiation, usually electromagnetic in character, that results from activation or contamination of the waste material; and contamination that may be transferred from the waste material and pose a hazard as a result of ingestion or inhalation, or by direct contamination of the skin and clothing. Contamination with alpha-emitting material is generally considered most dangerous because of the high energies involved; and because if unaccompanied by beta-gamma radiation, alpha particles are frequently difficult to detect.

Protection against direct radiation and contamination is provided for by strict adherence to standard procedures designed to ensure proper packaging, shielding, and handling of the waste. These procedures delineate the methods to be used in various situations and specify the type of protective clothing to be worn and the kind and extent of radiation monitoring required.

In particular a radiation work permit or equivalent is required in advance of any work assignment where an individual might receive a radiation dose in excess of 20 mrem/day to the body or 300 mrem/day to the extremities, or where the individual will encounter airborne radioactivity greater than MPC_a for a 40-hr week. Special approvals are required where radiation or contamination may be in excess of these values (Procedure 3.6 in ref. 1).

The radiation work permit shown in Figs. 35a and 35b is authorized by the member of supervision responsible for the work being done, and must be certified by a representative of the Health Physics Division. As can be seen, the permit describes the location and the job, contains information concerning the type and magnitude of the radiation hazard involved, and specifies the precautions and necessary protective equipment and monitoring instruments required. In addition, all personnel involved in waste storage operations are required to wear film badges, personal dosimeters, and pocket meters. The pocket meters are read daily by the Radiation Monitoring Section of the Health Physics Division.

RADIATION WORK PERMIT (RWP)

DATE AND TIME FROM	AM PM	TO	AM PM	EXTENDED BY TO	AM PM	WORK PERMIT NO.
						R- 36215

LOCATION & JOB DESCRIPTION

RADIATION SURVEY DATA (To be filled in by Health Physics)

LOC. CODE	SPECIFIC LOCATION AND DISTANCE FROM SOURCE	TYPE OF RADIATION	mrem/hr.	WORKING TIME FOR ______ mrem	CONTAMINATION TYPE	CONTAMINATION MEASUREMENT	RADIATION SURVEY BY	RADIATION SURVEY DATE AND TIME
A								
B								
C								
D								

INSTRUCTIONS*

HEALTH PHYSICS MONITORING REQUIRED: ☐ START OF JOB ☐ INTERMITTENT ☐ CONTINUOUS ☐ END OF JOB

CONTACT HP FOR SURVEY BEFORE STARTING WORK IN A NEW LOCATION		PROVIDE ASSISTANCE FOR REMOVAL OF PROTECTIVE CLOTHING	
TAPE COVERALLS TO GLOVES AND FOOTWEAR		MONITOR BREATHING ZONE	
CHECK TOOLS AT END OF JOB		NASAL SMEAR REQUIRED	
CHECK PERSONNEL AT END OF JOB		BIOASSAY SAMPLE REQUIRED	
TIMEKEEPING REQUIRED		DO NOT WORK ALONE-STANDBY OBSERVER REQUIRED	

PROTECTIVE EQUIPMENT AND MONITORING INSTRUMENTS

CAP		COVERALLS (1 PR.)		SHOE COVERS		POCKET METERS	
CANVAS HOOD		COVERALLS (2 PR.)		C-ZONE SHOES		DOSIMETER	
SAFETY GLASSES		GLOVES: CANVAS		RUBBERS		FILM RING	
EYE SHIELD		GLOVES: LEATHER		RUBBER BOOTS		DOSE-RATE ALARM	
HALF MASK		GLOVES: SURGEON'S		PLASTIC BOOTEES		DOSE ALARM	
ASSAULT MASK		GLOVES: PLASTIC		LAB COAT		CUTIE PIE	
CHEMOX MASK		GLOVES: RUBBERIZED CANVAS		SPECIAL FILM METER		GMS METER	
AIR-LINE HOOD		GLOVES: HOUSEHOLD RUBBER					
AIR-LINE SUIT							

REMARKS

REGULAR APPROVALS	SPECIAL APPROVALS
HEALTH PHYSICS CERTIFICATION	DIVISION DIRECTOR
SUPERVISION	H.P. DIVISION DIRECTOR
SUPERVISION	DEPUTY LAB DIRECTOR

UCN-2779 (3 7-61) *Only items checked (√) apply. (OVER)

Fig. 35a. Radiation work permit (UCN-2779).

1. Health Physics shall be present for line breaks or removal of shielding.
2. Notify Health Physics of any deviations from instructions and changes in working conditions.
3. Personnel survey is required when leaving contamination zones.
4. Return work permit to Health Physicist upon completion of job or expiration of permit.

TIMEKEEPING BY ____________________

DEPT. ____________________

PERSONNEL AND EXTERNAL EXPOSURE CONTROLS						PLANNED EXPOSURE (mrem)	TIME RECORD							ESTIMATED EXPOSURE (mrem)
NAME	DEPT.	P.R. NO.	LOCATION CODE	DOSE RATE USED	WORKING TIME		BEGIN	END	BEGIN	END	BEGIN	END	TOTAL TIME	

1. **Radiation Work Permit is required* when:**
   (a) expected dose is >20 mrem to the body or 300 mrem to extremities for an individual during a single work assignment;
   (b) dose rate >5 rem/hr (total body);
   (c) airborne radioactivity is > $(MPC)_a$ for a 40-hr week;
   (d) specified by divisional operating rules and procedures or by posted regulations.
2. **Supplementary Time Sheet**
   To be used if extra space is needed for the timing of individuals into and out of an area, etc.
3. **Special Approvals**
   (a) Dose Rate rem/hr (total body)

>5	Division Director in charge of work area	Oral or written; noted and initialed on the permit by the person obtaining the approvals.
>20	Above and Health Physics Division Director.	
>50	Above and Laboratory Deputy Director.	

   (b) Dose (total body)

>60 mrem/day for nonoperating personnel, or >300 mrem/wk for operating personnel	Division Director in charge of individual
>1 rem	Above and Laboratory Deputy Director

4. **Copies**
   (a) The RWP must be posted or available at work site.
   (b) Health Physics maintains a copy for record and reference purposes.
   (c) A copy must be distributed to appropriate line supervision.

*Posted regulations may be used in lieu of an RWP for *operating personnel* under specified conditions. (See Regulation 3, Procedure No. 26, ORNL Health Physics Manual.)

Fig. 35b. Radiation work permit (UCN-2779).

The procedures followed to prevent direct radiation exposure and contamination during the waste handling operations have been described in Part I and will not be repeated here. However, in general, the overriding precept is constant vigilance and surveillance by direct supervision and by the individuals performing the work, all of whom have received training in radiation safety. In many cases assistance is also provided by members of the Radiation Safety and Surveys Section who are present whenever potentially hazardous operations are in progress.

(2) Criticality hazards

Criticality is prevented by strictly limiting the amount of material to be handled in a single package or disposed of in a given storage facility. The quantities of fissionable material that may be stored in a single container (Table 1) were established so that an infinite array of containers would be safely subcritical. Bulk material containing less than 1 g/ft^3 of fissionable material may be safely stored in a semi-retrievable fashion because it is sufficiently dilute so that no possibility of criticality exists.

Note that the foregoing restrictions on criticality apply strictly to combinations of the more common fissionable nuclides; namely, ^{235}U, ^{233}U, and ^{239}Pu. Certain of the transuranium isotopes such as ^{242m}Am, ^{245}Cm and several of the californium isotopes are known to have very small minimum critical masses[2] (Appendix I). In the past, there were not sufficient quantities of these materials in existence to present a potential problem, however, with the increasing utilization of nuclear power plants, more and more of these nuclides are being accumulated, and interim guidelines for handling them have been developed (Appendix B). This problem, of course, is not restricted to the solid waste storage operations, and the ORNL Health Physics Manual will be updated to include recommended mass limits for all fissionable isotopes.

In any case where a question regarding criticality safety exists, or where for some reason the specified limits must be exceeded, the problem is submitted to the ORNL Criticality Committee for review and recommendations.

(3) Neutron sources

Occasionally, neutron-emitting wastes must be stored. Usually, these wastes consist of fissile alpha transuranium wastes that contain trace amounts of the neutron-emitting "even-even" nuclei. As described in Part I, these materials are normally handled by utilizing shielded containers that reduce the neutron emission to levels sufficiently low to meet the requirements of ORNL radiation protection policy.

Certain materials such as beryllium and deuterium emit neutrons when exposed to high energy sources of electromagnetic radiation. When possible, these photoneutron sources are disassembled prior to disposal; however, when this is not feasible, they are appropriately shielded prior to handling and transportation to the SWSAs. Health physics and supervisory surveillance requirements similar to those employed in handling other radioactive wastes are observed.

B. Industrial

The normal industrial hazards that accompany the solid waste storage operation are similar in character to those associated with an operation involving excavation, lifting, hauling, and the employment of heavy construction equipment. As is the case with radiation induced hazards, protection is afforded by constant vigilance and surveillance by direct supervision and by the individuals performing the work, all of whom receive training in the fundamentals of industrial safety.

The policy of ORNL is to prevent personal injury and property damage by maintaining standards of safety consistent with national codes and standards. The following list contains the standards having particular application to the solid waste disposal operation:

AEC Manual Chapter 0550 — Operational Safety Standard
AEC Manual Chapter 0522 — Industrial Fire Protection
ORNL Standard Practice Procedure 16 — Safety Standards
ORNL Standard Practice Procedure 17-D — Laboratory Emergency Planning and Evaluation
ORNL Standard Practice Procedure 35-B — Industrial Health Series
ORNL Standard Practice Procedure 55-D — Fire Prevention and Control
ORNL Safety Manual
Occupational Safety and Health Act, in particular, Sections 1910 and 1926
Plant and Equipment Division Safety Manual
Plant and Equipment Division Procedures:
- M.3.4 Solid waste disposal cask — TRU facility
- M.3.6 Handling and transfer of shielded carriers
- M.3.9 Qualification tests for industrial operation of lift trucks

Inspection Engineering Manual:
- Section 1. Inspection of purchased material
- Section 9. Visual inspection
- Section 10. Upgrading materials
- Section 14. Inspection of testing and hoisting equipment

As a result of vigorous prosecution of its safety program, the Laboratory has achieved in the past, and continues to achieve, an outstanding record of industrial safety. This record is graphically illustrated by the statistics given in Table 3.

Table 3. Comparison of disabling injury frequency rates of ORNL (from time of operation under contract with Union Carbide), NSC,[a] and AEC

Year	ORNL	NSC	AEC
1948	2.42	11.49	5.25
1949	1.54	10.14	5.35
1950	1.56	9.30	4.70
1951	2.09	9.06	3.75
1952	1.39	8.40	2.70
1953	1.43	7.44	3.20
1954	0.79	7.22	2.75
1955	0.59	6.96	2.10
1956	0.55	6.38	2.70
1957	1.05	6.27	1.95
1958	1.00	6.17	2.20
1959	1.44	6.47	2.15
1960	0.94	6.04	1.80
1961	1.55	5.99	2.05
1962	1.45	6.19	2.00
1963	1.55	6.12	1.60
1964	1.07	6.45	2.05
1965	2.34	6.53	1.80
1966	0.64	6.91	1.75
1967	0.50	7.22	1.55
1968	0.13	7.35	1.27
1969	0.27	8.08	1.52
1970	0.76	8.87	1.28
1971	0.61	-	1.31

[a]National Safety Council (NSC), all industries.

4. Environmental hazards

The primary purpose for disposing of solid waste by storing it below grade is to effectively remove it from the environment. While ground burial does accomplish this purpose over the short term, there is growing concern over the eventual fate of the extremely long-lived radionuclides. Consequently, the current practice is to store these long-lived materials in a retrievable fashion pending the development of a more permanent method of storage.

As described in Section 1, the solid waste storage areas are located within the ORNL reservation on land owned and controlled by the U.S. Atomic Energy Commission. The reservation is fenced, provided with appropriate warning signs, regularly patrolled, and prohibited to the public. Some areas of SWSA-5 are individually fenced with woven fabric as is all of SWSA-3. A request for funds to provide security fencing for SWSA-6 has been submitted.

Current practice is to grade and seed with grass those portions of the SWSAs that have been closed. Trees and underbrush that might send roots into the closed trenches are removed, and the area is posted to indicate its character (Fig. 36). Hence, with the exception of some seepages discussed later, the land surface is essentially free of contamination.

While the radiation level at the top of an open trench or auger hole may be as high as 200 mR/hr, the trench or auger hole is backfilled until the maximum radiation reading above the closed facility is 3 mR/hr or less. Usually, the actual radiation level from closed facilities is much lower.

PHOTO 1209-74

Fig. 36. Portion of SWSA-4 after closure.

The level of radiation in the aisles within the aboveground storage building is held to less than 10 mR/hr. Occasionally, containers with "hot spots" of varying levels are received. When these containers cannot be shielded with other containers in the building, special arrangements are made to reduce the radiation intensity to the appropriate level.

In any case, the SWSAs are all regarded as regulated, radiation, or contamination zones as appropriate (Appendix C) and are posted as such. Hence, there is little, if any, danger of a direct hazard to the public as a result of the presence of buried waste in the SWSAs.

With three exceptions, no significant amount of rapidly available stored energy is associated with the waste. None of the material is under pressure; it is essentially chemically inert; and the possibility of inadvertent criticality is prevented by the precautions described in Part II, Section 3(C)(2).

The exceptions involve the disposal by ground burial of small quantities of contaminated lubricants such as cutting oil and vacuum pump lubricant and the practice, now largely discontinued, of burying alkali metals. In addition, small quantities of pyrophoric materials such as metallic zirconium and magnesium must occasionally be disposed of. All of these materials are disposed of in separate trenches or holes at a sufficient distance from other trenches to prevent any interaction, should an energy release occur.

Waste material stored in a retrievable form in auger holes or aboveground in SWSA-5 is within a fenced security area. The capped auger holes are shielded, when necessary, to reduce the direct radiation in their vicinity to an acceptable level, and the material stored aboveground in Building 7823 is controlled to meet health physics requirements. Thus, as in the case of the below-grade storage, these aboveground wastes which are located at least 1000 ft from the nearest public access, do not present a direct hazard to the public.

Aside from the commitment of about 150 acres of land for the SWSAs, the only environmental hazards which arise from this operation are associated with the possibility that the contaminated waste material may in some way be conveyed from its present location and find its way into the environment. With respect to the buried material or that located in auger holes, one obvious way this could occur is by water seepage, which could carry either entrained or dissolved radionuclides into the White Oak Creek watershed and then to the Clinch River. Another is as the result of an earthquake of sufficient magnitude to severely disrupt the land surface in the vicinity of the SWSAs.

The material stored aboveground could be dispersed by a storm of sufficient violence to destroy the integrity of the containers, or again, by an earthquake. Once the containers are ruptured, the radioactive material could be dispersed either by water runoff or in some instances, it might become airborne.

The remainder of this review will be devoted to a discussion of the possibilities and consequences of such events and to recommended methods of dealing with them.

A. Seepage

Currently, the only off-area environmental effect that can be attributed to the SWSAs results from groundwater seepage that carries dissolved or entrained radioactive material into White Oak Creek. The radionuclides involved are ^{3}H and ^{90}Sr.

Tritium has been observed at the mouth of White Oak Creek for many years. The annual quantities delivered to the creek since 1964 are shown in Table 4. Starting in 1967 there was a dramatic increase in the quantity delivered to the creek. This increase was investigated and the evidence[9] indicated that the tritium originated in shipments of material received from Mound Laboratory prior to 1967. This waste material was disposed of in SWSA-5.

Table 4. Radioactivity discharges to White Oak Lake attributed to seepage from solid waste storage areas

Year	Quantity (Ci/Year) Tritium[a]	Strontium-90[b]
1964	1,930	3.36
1965	1,160	3.48
1966	3,100	1.92
1967	13,270	2.76
1968	9,690	1.92
1969	12,250	1.33
1970	9,470	1.35
1971	8,950	1.19
1972	10,600 (1060)[c]	1.97
1973	15,050 (760)[c]	2.19

[a]Total entering White Oak Lake from all sources.

[b]Difference between sampling points 1 and 3.

[c]Numbers in parentheses represent contribution from main branch of White Oak Creek.

Recent investigation indicates that this is indeed the case. Samples taken in Melton Branch at sampling point 4 and at sampling point 2 on White Oak Creek indicate that 90% of the tritium is coming from Melton Branch (Fig. 37), and the quantity originating upstream from the junction of the two creeks is of about the same order of magnitude as that observed for the total prior to 1967.

Although rather large quantities of tritium are being discharged to the Clinch River, this problem is not regarded as acute at this time. Taking into consideration the mean river flow of 4200 cfs, a discharge of 1 Ci/year from White Oak Creek represents a mean concentration in the river of 2.67×10^{-10} μCi/ml. The most restrictive guideline value for tritium in water[9] is 10^{-3} μCi/ml. Hence, an annual discharge of nearly 40,000 Ci/year would be required to produce a concentration in the river which exceeds 1% of the guidelines. As can be seen from Table 4, the current rate of discharge is well below this figure.

As a result of differences discovered in the amount of ^{90}Sr transported past sampling point 1 and sampling point 3, the conclusion was reached that small quantities of ^{90}Sr (Table 4) are being leached from SWSA-4. This leaching is believed to be caused by the fact that SWSA-4 is located very near to the water table and the contents of some of the trenches are saturated during periods of high rainfall. Note, however, that there seems to be no obvious correlation between monthly rainfall and the amount of ^{90}Sr delivered from this source. On the other hand, there is a linear relationship between monthly creek flow and ^{90}Sr delivered as shown in Fig. 38. This relationship implies that the ^{90}Sr concentration in the creek from this source is essentially constant.

ORNL DWG. 73-9051

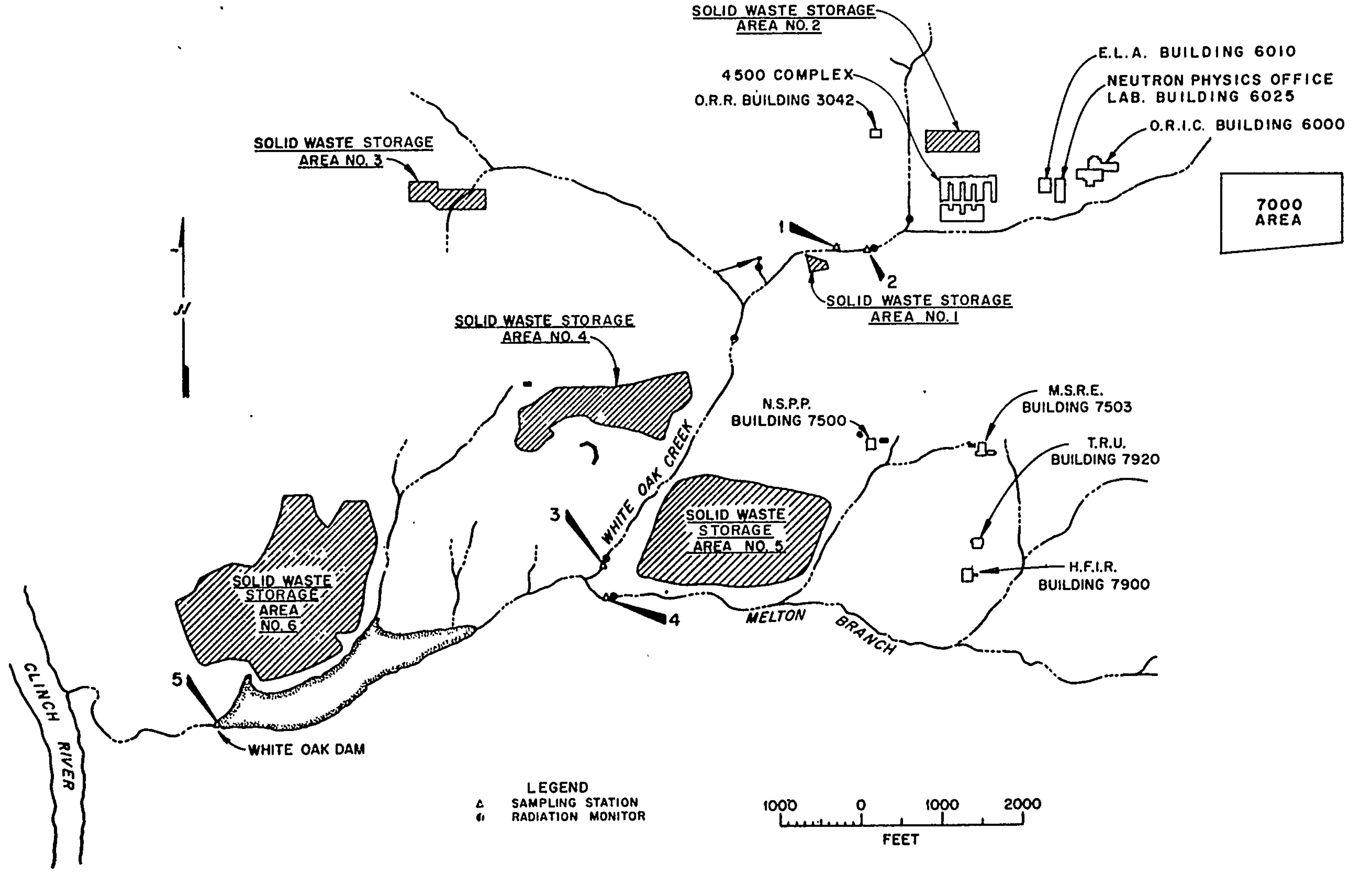


Fig. 37. Location plan of ORNL solid waste storage areas.

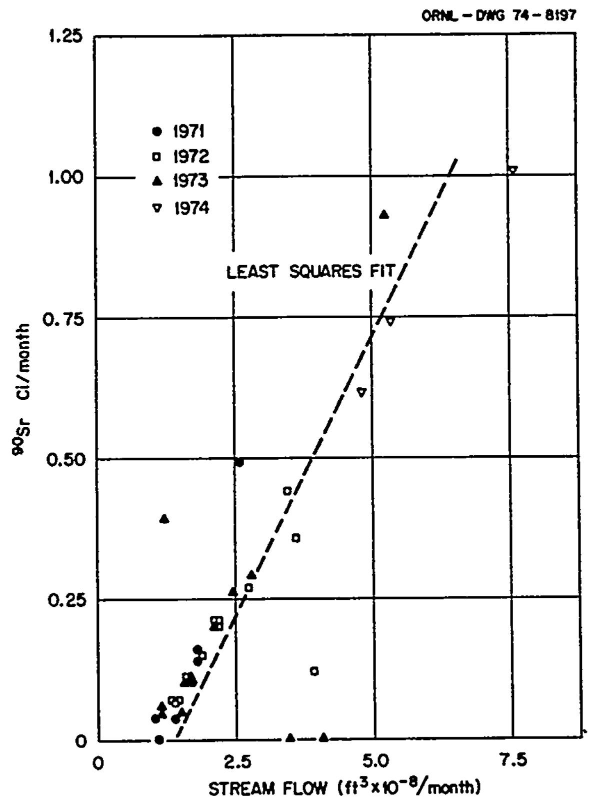


Fig. 38. Apparent ^{90}Sr contribution to White Oak Creek from SWSA-4 (June 1971 - March 1974).

Again, this seepage is not regarded as a serious problem. The most restrictive value in the concentration guides (Appendix H) for ^{90}Sr in water is 3×10^{-7} μCi/ml. Hence, about 11 Ci/year are required to reach 1% of this value in the river. At present, the discharge rate is of the order of 1 or 2 Ci/year.

Despite the fact that seepage does not constitute an environmental hazard at this time, the Laboratory instituted a study of the problem in the summer of 1973. This study, conducted by the Environmental Sciences Division, has the objectives of determining the specific contributions from the various potential sources of radioactivity discharged to the Clinch River, and of seeking methods of reducing them. Results of the study which is expected to extend at least through fiscal 1975 cannot be included in this review but will be published separately.

Among the preliminary findings is the very strong implication, based upon preliminary sampling, that there is no significant seepage of ^{90}Sr from SWSA-1, -2, -3, or -5. SWSA-6 has not yet been examined. Except for SWSA-5, the SWSAs contain little or no tritium.

B. Natural disasters

Aside from the seepage problem, which could of course be exacerbated by heavy rainfall, the only possible spontaneous causes of significant environmental hazard are from naturally occurring events such as fires, floods, tornadoes, or earthquakes.

(1) Fire

Much of the waste stored by burial below grade consists of wood, paper, cloth, and other combustible materials. Once the storage trenches have been backfilled, these materials no longer present a fire hazard; however, during the period when the trench is in active use prior to filling, a fire hazard does exist, and care is taken to prevent ignition of the material. The ordinary precautions associated with operation within a contamination zone are sufficient to reduce the hazard of fire to an acceptable level.

In the past, a few instances of either combustion or rapid oxidation of waste have occurred as a result of inadvertent mixture of the waste with strong oxidizing agents such as nitric acid. This interaction is accompanied by the emission of fumes from the trench, but is readily extinguished by immediate backfilling of the area involved. Consideration is being given to methods of preventing such occurrences.

The material stored in a semi-permanent fashion in auger holes or aboveground is essentially noncombustible.

One other source of hazard is the occasional storage of pyrophoric materials such as relatively finely divided metals, particularly such metals as zirconium and magnesium. Under certain conditions, these metals are known to undergo rapid spontaneous oxidation that can result in the rapid release of substantial quantities of energy. Handling of such materials is rare; but when necessary, they are packaged in containers approved individually by both the ORNL Fire and Safety Departments, handled as a special individual shipment, and stored in a section of the SWSAs sufficiently far removed from all other material so that there is no possibility of interaction. Such materials are covered with earth immediately after they are placed in the trench.

Uranium and plutonium metal are also pyrophoric; however, they are virtually never disposed of in the SWSAs. Any requirement for such disposal would require special approval by the appropriate committees (Part I, Section 7).

As pointed out previously, the disposal of alkali metals by burial has largely been discontinued; however, should such burial become necessary, precautions similar to those described above would be taken.

The Laboratory has a resident fire department on duty 24 hr/day, trained to handle the type of emergencies that could arise and adequate to handle any foreseeable situation.

(2) Floods

Based on data supplied by the Tennessee Valley Authority,[10] the maximum probable flood in the area in which the SWSAs are located could reach an elevation of 768.5 ft, which is below the minimum elevation of the bottom of the lowest trench. Thus, a flood would not be expected to directly affect the SWSAs. The precipitation necessary to cause such a flood would, however, aggravate the seepage problem described in Part II, Section 4(A).

(3) Tornadoes

Below-ground storage, once backfilled, is essentially invulnerable to high winds even of tornado force. The same is true of the material stored in auger holes.

The greatest hazard that could result from a tornado would be a funnel passing directly across an open trench that had not yet been backfilled. In this circumstance, some contaminated material could be scattered over a considerable area; however, the likelihood of this is small.

A study of tornado occurrences in Tennessee[11] indicates that the incidence of this type of storm in the broken terrain characterizing the immediate vicinity of the Oak Ridge National Laboratory is quite rare, although numerous tornadoes have been reported in the broad valleys southwest and northeast of the area (Fig. 39 and Key to Fig. 39).

On May 2, 1953, at approximately 3:30 a.m., a small tornado passed through the AEC Reservation on a track which brought it to within two or three miles of the SWSAs. This is the only recorded case of such a storm on the reservation during its 30 years of existence. Based upon a relationship developed by the U.S. Weather Bureau,[12] the expectation that a tornado would strike a given point in the ORNL vicinity is approximately once in 2500 years.

The only other SWSA facilities vulnerable to tornadoes (aside from office buildings) are the aboveground storage buildings (7823 and 7824) currently being used for retrievable storage (see Part I, Section 4A). Use of Building 7824 for storage of radioactive material will be discontinued in the near future and the material now stored there disposed of below grade.

Building 7823 is protected because most of the structure is placed below grade, with only the overhanging saddle roof exposed (Part I, Figs. 11a and 11b). A tornado would undoubtedly remove this roof, either in whole or in part, because of its aerodynamic properties, and deposit it in some nearby area. The steel structure of the building, because of its anchorage below grade, would remain intact. This remaining structure and the below-grade position of the stored drums offer protection similar to that provided by western prairie storm cellars from the vortex-induced forces. Scattering of the drums within the shelter will take place, and conceivably some drums might be ruptured by impact with the steel structure or the side walls of the below-grade shelter. Because of the presence of the steel fencing located in the roof and the fact that the drums are palletized, the drums would probably not be transported outside the building.

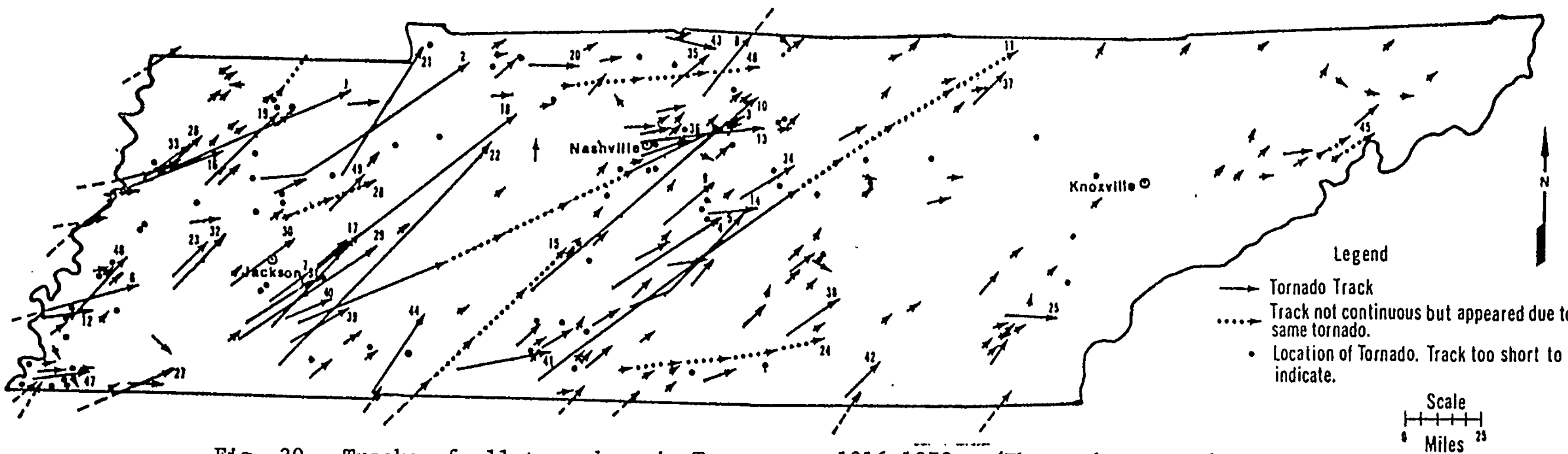


Fig. 39. Tracks of all tornadoes in Tennessee, 1916-1970. (The numbers at the arrow heads correspond to the sequence of numbers in the Key to Fig. 39: Tornado tracks whose lengths were 15 miles or longer.) Source: Reference 11.

Key to Fig. 39

Tornado tracks whose lengths were 15 miles or longer

Number	Date	Location	Length (miles)
1	1917, May 27	Entered Tennessee near Chic, Dyer Co. to NW Henry Co.	80
2	May 27	Trenton, Gibson Co. into Carroll Co. then northeast to Stewart Co.	90
3	May 27	Finger, McNairy Co. to Lebanon, Wilson Co.	130
4	1921, Mar. 24	SE Maury Co. to SE Murfreesboro, Rutherford Co.	40
5	Apr. 16	Cornersville-Palmetto area, Marshall Co. to Readyville, Rutherford Co.	50
6	Dec. 23	Entered Tennessee NW Shelby Co. to SE Covington, Tipton Co.	33
7	1923, Mar. 11	Chester Co. into Madison Co.	15
8	1925, Mar. 18	NW Gallatin, Sumner Co. into Kentucky	23
9	Mar. 18	College Grove, Williamson Co. to Walterhill, Rutherford Co.	20
10	1932, Mar. 21	SE Lewis Co. to Trousdale Co.	90
11	Mar. 21	Entered Tennessee SE Lawrence Co. to Scott Co.	180
12	Apr. 25	Locke-Rosemark area, Shelby Co.	16
13	1933, Mar. 14	Across Nashville, Davidson Co. to Lebanon, Wilson Co. into Smith Co.	40
14	1935, Mar. 25	Rutherford Co. into Cannon Co.	15
15	1936, Apr. 5	E Hardin Co. to near Columbia, Maury Co.	65
16	1938, Mar. 15	First observed at Hales Point, Lauderdale Co. into NW Gibson Co.	30
17	1939, Jan. 4	Near Silerton, Hardeman Co. into Henderson Co.	40
18	1940, Mar. 2	Huron, Henderson Co. to Slayden, Dickson Co.	80
19	Nov. 11	Crockett Co. into Weakley Co.	32
20	1942, Jan. 1	SE Clarksville, Montgomery Co. to Robertson Co.	15
21	Mar. 16	Huntingdon, Carroll Co. to NW Stewart Co.	45
22	Mar. 16	W Selmer, McNairy Co. across Chester and Decatur Co. into Humphreys Co.	95
23	1947, Jan. 29	Haywood Co.	15
24	1952, Feb. 13	E Giles Co. to Grundy Co.	60
25	Feb. 29	McMinn Co.	15
26	Mar. 21	Unionville-Newbern area, Dyer Co.	18
27	Mar. 21	Entered Tennessee SE Rossville to near Moscow, Fayette Co.	20
28	Mar. 21	Gibson Co. to Carroll Co.	30
29	Mar. 21	Bolivar, Hardeman Co. to Chesterfield, Henderson Co.	50
30	1953, Mar. 14	Across Madison Co.	25
31	Mar. 14	NE Hardeman Co. into Chester Co.	25
32	Mar. 14	Across Haywood Co. into Madison Co.	25
33	Mar. 22	NW Lauderdale Co. to Dyersburg-Newbern area, Dyer Co.	30
34	1955, Mar. 5	Wilson Co. into DeKalb Co.	20
35	1956, Feb. 27	White House-SE Portland area, Sumner Co.	15
36	1957, Jan. 22	Across S Nashville, Davidson Co. into Wilson Co.	15
37	Nov. 8	Fentress Co.	15
38	1959, Mar. 26	Alto, Coffee Co. to Altamont, Grundy Co.	20
39	1961, May 8	Vicinity Logan Lake, McNairy Co. to Enville, Chester Co.	20
40	1962, Feb. 23	Near Henderson to Jacks Creek in Chester Co.	15
41	1963, Mar. 11	S Collinwood, Wayne Co. to near Bodenham, Giles Co.	30
42	Mar. 11	Marion Co. (New Hope to Sequatchie)	15
43	Mar. 19	NE Orlinda, Robertson Co. to ESE Portland, Sumner Co.	15
44	1964, Mar. 4	Counce, Hardin Co. to Clifton Junction, Wayne Co.	29
45	1967, Mar. 12	Greene Co.	15
46	1968, Apr. 3	Millington, Shelby Co. to Covington-Gift area, Tipton Co.	25
47	1970, Apr. 24	Memphis-Capleville area, Shelby Co.	18
48	Apr. 27	Montgomery-Cheatham Co. line to New Zion, Macon Co.	62
49	Nov. 19	Clarksburg-Bruceton area, Carroll Co.	15

Source: Reference 11

Funds have been requested to replace Building 7823 with a new below-grade structure, and the material stored in 7823 will be moved to the new storage facility as soon as it is completed.

The new Retrievable Waste Storage Facility, Fig. 40, has been designed for resistance to the AEC Design Basis Tornado (DBT)[13] to the following extent:

The building walls are protected from wind loading by earth backfill to a sufficient height to withstand DBT wind loading.

The roof system is designed so that end spans of the roof panels will blow out when subjected to internal pressure or wind uplift loading of approximately 1 psi. These "blow out panels" constitute approximately 25% of the roof surface and should provide sufficient venting so as to preclude internal pressure buildup significantly greater than 1 psi. The roof framing system is designed to withstand a uniform uplift loading of approximately 2 psi before failure.

In the event of a "hit" by a DBT with 360 mph winds and ±3 psi pressure differentials, a high percentage of the roof panels would probably be removed either by wind loading or by pressure differential. However, analyses indicate that the roof framing structure would remain intact and would provide a barrier for stored drums that might tend to be ejected into the air stream. The top and bottom purlins will be staggered to provide a minimum clear space between roof framing members of less than 2 ft. Since the drums are 25 in. in diam, a purlin spacing of 2 ft would not allow free passage of an ejected drum. The probability of a drum becoming airborne is reasoned to be extremely remote.

In a recent study undertaken for the purpose of determining tornado risks and design wind speeds in the Oak Ridge area, J. R. McDonald[14] has concluded that the probability of wind speeds exceeding those of the DBT is about 3×10^{-7} per year and that the probability of wind speeds exceeding 130 mph is about the same as the tornado frequency calculated above using Thom's[12] method. It would appear, therefore, that the proposed building is completely adequate to protect against the effects of wind and pressure.

The only credible occurrence that could cause the release of any of the contaminated material from the new Retrievable Waste Storage Facility would be penetration of the roof by a missile having sufficient kinetic energy to rupture one or more of the drums and subsequent entrainment of some of the contaminated material in the air stream.

The total quantity of fissile-alpha material contained in these drums is less than 4 kg or an average of about 6 g per drum. In general, the material in the drums consists of contaminated trash, such as paper, glassware, rubber, plastic, etc., so the material released would not form an aerosol and hence could not become an inhalation hazard. Moreover, because of the low level of activity present, it would not likely become a direct radiation hazard. On the other hand, the random dispersal downwind

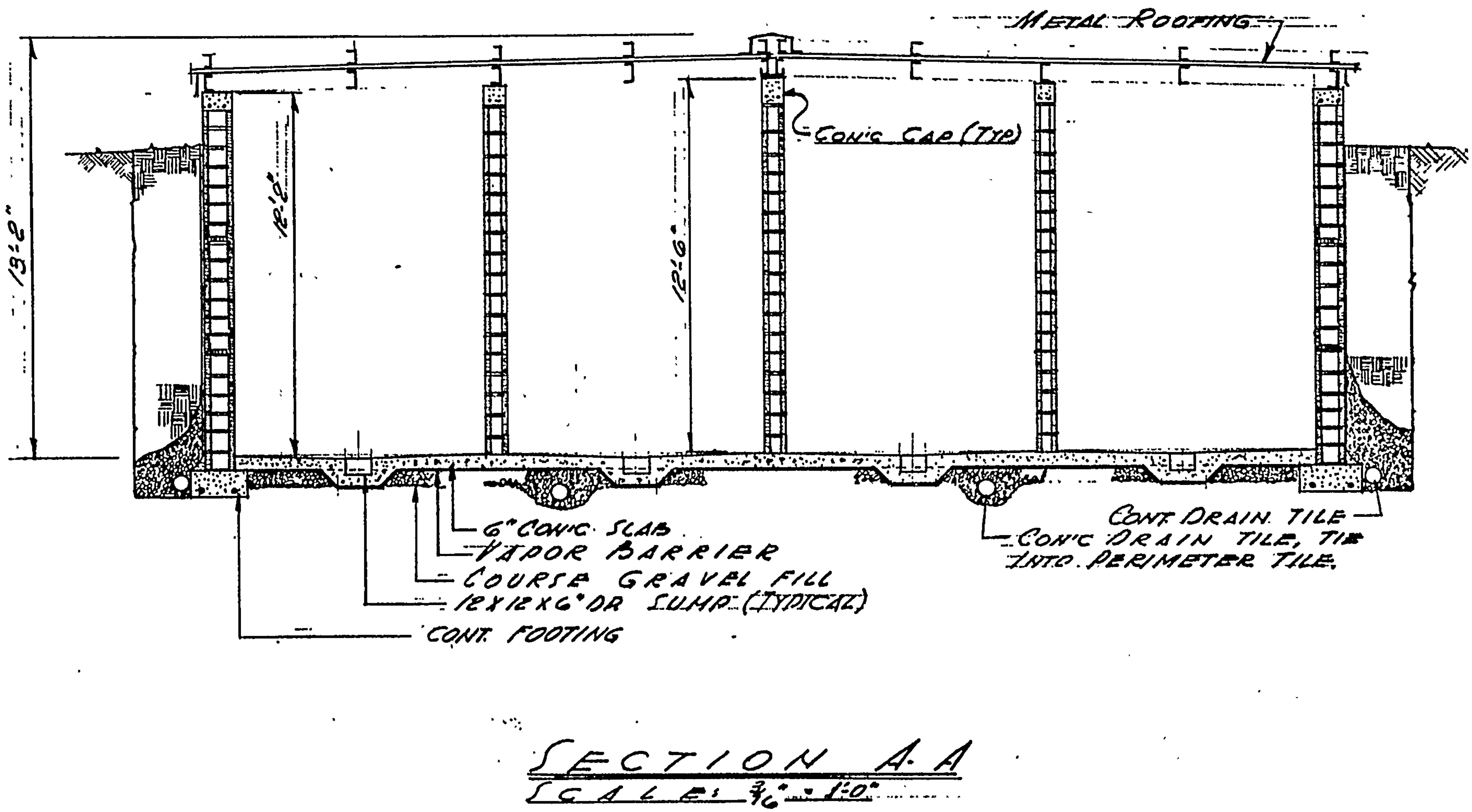


Fig. 40. Cross section of storage facility for retrievable waste (Building 7826).

of small quantities of contaminated trash could pose a contamination hazard that, while not widespread, would be difficult to locate and clean up.

Because of the random and unpredictable nature of tornadoes and other violent storms,[15] making a rational quantitative prediction of the area over which the contaminated material would be dispersed is impossible; however, because of the nature of the terrain and the fact that in most cases tornadoes move from southwest to northeast, the debris would probably be carried northeast along either Bethel or Melton Valley. In this direction, the distance from the facility to the nearest populated area is more than 7 km.

The foregoing conclusions apply also to the present retrievable storage building (7823) with a somewhat higher probability of occurrence; however, as has been pointed out above, the use of Building 7823 for storage will be discontinued as soon as the new structure is completed.

(4) Earthquakes

The Oak Ridge reservation is located in an area of moderate earthquake damage (Zone 2). As can be seen from Fig. 41, the reservation is about midway between the Zone 3 areas of more significant damage that are centered around Charleston, South Carolina, and Memphis, Tennessee. These areas are about 400 miles from Oak Ridge.

Data on earthquakes prior to 1900 are extremely fragmentary; there is only one reported shock with an epicenter within 100 miles of Oak Ridge and an intensity greater than V (modified Mercalli scale) for this period.[16] Since 1900, there were 15 reported shocks with an epicenter within 100 miles of Oak Ridge and an intensity of V; three shocks of intensity V-VI, seven shocks of intensity VI (a few instances of fallen plaster or damaged chimneys), three shocks of intensity VI-VII, one shock of intensity VII (damage negligible to buildings of good design and construction), and no shocks of intensity greater than VII. The one shock of intensity VII occurred on March 29, 1913, and had an epicenter near Knoxville, Tennessee. The nearest recorded earthquake with an intensity greater than VII occurred in January, 1905, and had an epicenter near Gadsden, Alabama, 170 miles away. This shock was of intensity VIII (damage slight in specially designed structures and considerable in ordinary buildings).

The Oak Ridge area has experienced a recent earthquake (November 30, 1973). The epicenter was about 30 miles southeast of the ORNL site with an intensity of IV-V. The intensity at ORNL was estimated at about IV and there was no observed damage.

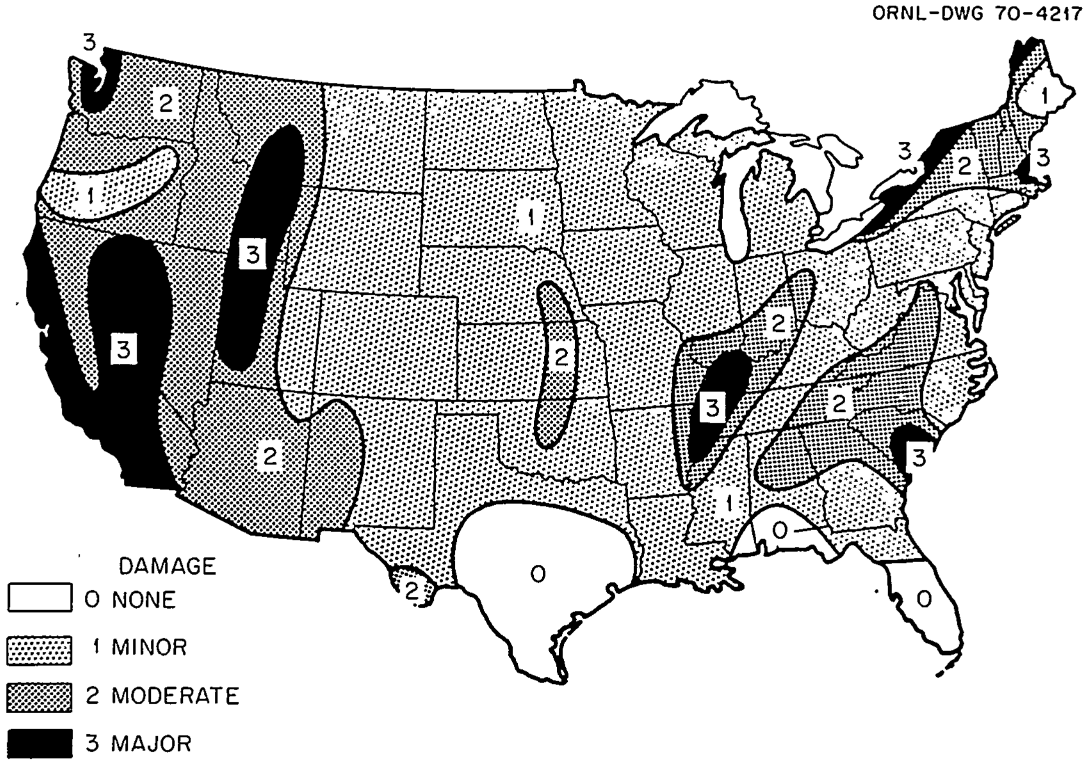


Fig. 41. Seismic risk map of the United States.

The only structure in the SWSAs that could be involved in a significant way if an earthquake occurred is the aboveground storage building (Building 7823). Conceivably, the building could collapse, the drums could be scattered within the building, and a few might open and spill their contents. However, this would only present a local contamination problem that the Laboratory emergency organizations are well experienced in handling.

An earthquake by itself would have no significant effect on underground conditions, although horizontal displacements could conceivably do considerable damage to the auger holes and make retrieval of the waste difficult.

For important changes to take place, faulting would have to occur. Faulting that accompanies a truly major earthquake may involve large vertical displacements. In hard brittle rock, large faults of this type may shatter the rock along the fault plane and make a highly permeable pathway. In soft rock such as shale, the rock along the fault is ground to powder, and the fault trace is impermeable. The trace of the Copper Creek thrust fault, which is about 230 million years old, was intersected at a depth of 1360 ft during a drilling operation. The fault plane was represented by 2 to 3 ft of finely crushed shale, quite impermeable, and showed by the lack of alteration or the deposition of any minerals such as calcite that no water had ever moved along it. Even an earthquake accompanied by faulting would thus be quite incapable of forming a permeable channel through the shale underlying the SWSAs. Therefore, a major earthquake would not cause the SWSAs to become a serious environmental hazard; however, considerable cleanup and repair work might be required.

5. Conclusions

The foregoing review shows that operation of the solid waste storage areas at the Oak Ridge National Laboratory presents no significant hazard to the public, nor, as the record shows, has it resulted in any significant safety hazard to the personnel involved in the operation. Despite this, there are a number of areas that require attention. These areas are under examination and, where feasible, appropriate steps will be taken to correct them.

(a) The study of seepage is being pursued to identify those conditions that may result in a hazard and to develop methods to cope with these conditions. This study will be extended to develop positive routine surveillance methods.

(b) At present, the composition of nearly all of the waste received is identified only by the originator. Operations personnel at the SWSAs have no facilities for opening and checking the packages, nor is such a procedure desirable or practical at this time. Methods for strengthening procedures for classifying and identifying wastes are under study.

(c) Because continually increasing quantities of transplutonium elements, some of which have extremely low minimum critical masses, are being generated, a review of the Laboratory's safety regulations regarding these materials is under consideration and comprehensive procedures to prevent any possibility of inadvertent criticality involving them will be developed.

(d) While burial of slightly contaminated waste is undoubtedly the quickest, cheapest, and perhaps safest way to remove it from the environment, the procedure is wasteful of land because it utilizes a very large area for the storage of a very small amount of radioactivity. Efforts to develop volume-reducing processes are being pursued.

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PART III. APPENDIXES

PART III. APPENDIXES

For convenience, a number of documents that are relevant to the solid waste disposal operations have been reproduced and collected as Appendixes so that they are available for reference.

A UCN Standard Practice Procedure D-5-15 and ORNL Supplement D-5-15, *Waste Management and Environmental Pollution Control.*

B ORNL Health Physics Manual, Procedure 5.1, *Disposal of Solid Radioactive Wastes.*

C ORNL Health Physics Manual, Procedure 2.7, *Radiation Control Zones.*

D ORNL Health Physics Manual, Procedure 2.4, *Source, Special Nuclear, and Special Materials Controls.*

E USAEC Manual, Chapter 0511, *Radioactive Waste Management*, and USAEC-ORO Manual, Chapter OR-0511, *Radioactive Waste Management.*

F ORNL Safety Manual, Procedure 2.4, *Hoisting Equipment.*

G USAEC Manual, Chapter 0550 and Supplement, *Operational Safety Standards*, and USAEC-ORO Manual, Chapter 0550, *Operational Safety Standards.*

H USAEC Manual, Chapter 0524, *Standards for Radiation Protection.*

I Excerpt from ORNL CF-72-6-16, *Estimated Safe Mass Limits for Actinide Isotopes.*

APPENDIX A

UCCND STANDARD PRACTICE PROCEDURE D-15-15 AND ORNL SUPPLEMENT D-5-15, WASTE MANAGEMENT AND ENVIRONMENTAL POLLUTION CONTROL

D SERIES

STANDARD PRACTICE PROCEDURE

UNION CARBIDE CORPORATION

NUCLEAR DIVISION

NUMBER	D-5-15	
DATE	March 15, 1973	R
PAGE	1 OF 3	

SUBJECT: WASTE MANAGEMENT AND ENVIRONMENTAL POLLUTION CONTROL R

5-15.1 MANAGEMENT OBJECTIVE: To exercise a continuous program of surveillance over UCC-ND operations and to establish safeguards against environmental pollution consistent with or more stringent than the requirements of established standards which assure that installation personnel, the general public, and the environment are protected against hazardous material.

5-15.2 RESPONSIBILITIES:

a. Each Installation:

1. Sees that every potentially significant pollution source is identified and its output of gaseous, liquid, or solid waste is measured in terms of concentration and quantity.
2. Requires that immediate remedial action is taken to correct any adverse trends in environmental quality resulting from plant operations.
3. Appoints an Installation Environmental Control Coordinator to serve in a liaison capacity between the Installation and UCC-ND Management, and to coordinate the Installation pollution abatement and monitoring programs.
4. Provides for review and approval by the Environmental Control Coordinator of all actions which may have an environmental impact.
5. Ascertains that employees are familiar with established Standard Practice Procedures relating to all aspects of effluent control applicable to the functions for which they are responsible.
6. Reviews operating practices to determine if operating procedures can be revised to reduce or control emissions.
7. Initiates studies for resolution of pollution problems where the nature of the effluents and quantities involved indicate problems that cannot be resolved by revising operating procedures.
8. Defines contaminant limits for each type effluent to assure total installation compliance with pollution control regulations as referenced in this procedure.
9. Identifies areas where development work is required for pollution abatement or monitoring.
10. Effects monitoring of the quantities and concentrations of materials released and reporting of data as required.
11. Assures that monitoring and reporting systems are adequate to define actual or potential pollution of the environment.
12. Maintains adequate records on significant effluents within the installation.
13. Provides for review of the design, acquisition, and installation of required pollution control equipment.
14. Prepares periodic analysis reports as required by UCC-ND Management and the AEC.

b. Office of Safety and Environmental Protection:

1. Serves in a liaison capacity between Installation Environmental Control Coordinators and the AEC and/or other official regulatory bodies on all matters relating to waste management and environmental pollution control.
2. Collects, collates and evaluates four-plant environmental data and coordinates the preparation of reports for UCC-ND Management and as required by the AEC.

APPROVED BY

SUBJECT: WASTE MANAGEMENT AND ENVIRONMENTAL POLLUTION CONTROL R

5-15.3 APPLICABLE STANDARDS: Airborne or liquid effluents shall be controlled in accordance with the provisions of the AEC Manual Chapter 0510, "Prevention, Control and Abatement of Air and Water Pollution"; Chapter 0511, "Radioactive Waste Management"; Chapter 0513, "Effluent and Environmental Monitoring and Reporting"; Chapter 0524, "Standards for Radiation Protection"; other related requirements in the AEC Manual; the applicable policies and guidance of local, state, and Federal regulatory bodies including the Environmental Protection Agency (EPA); and UCC-ND Standard Practice Procedures.

5-15.4 DEFINITIONS:

a. Effluents. (As used in this procedure) Refers to liquid and airborne waste streams which are released to the environment and does not include solid wastes nor waste streams which are contained or stored.

b. Air Pollutants. Refers to dust, fumes, gases or radioactive emissions discharged to the atmosphere.

c. Water Pollutants. Refers to thermal, radioactive, or otherwise contaminated liquid or liquid-borne solid wastes discharged to the environment.

d. Solid Waste Disposals. Refers to burial grounds (radioactive, toxic, and sanitary landfills), quarry disposal operations, steam plant ash disposals and general waste disposals.

e. Burial. Refers to a form of warehousing or permanent storage requiring some degree of perpetual care and may be categorized as an effluent source only when seepage or leaks occur.

5-15.5 MONITORING:

a. Effluent Monitoring. Effluent monitoring is conducted to provide adequate measurement of liquid and airborne effluents as a basis for:

1. Obtaining data on the quantities and concentrations of pollutants released to the environment for the purpose of evaluating the adequacy and effectiveness of containment, effluent treatment methods, and overall effluent control.

2. Determining compliance with applicable effluent control limits or release standards, including self-imposed standards designed to assure compliance with in-plant standards or guides.

b. Environmental Monitoring. Environmental monitoring is conducted to provide adequate measurements of pollutants in various environmental media as a basis for:

1. Obtaining data on the quantities and/or concentrations of pollutants in the environment for the purpose of evaluation and control of environmental impact.

2. Determining compliance with applicable environmental standards.

3. Detecting environmental trends related to plant operations which could result in unacceptable environmental effects.

c. Monitoring Locations. Measurements of effluents are made, insofar as is practicable, at the point of final release to the environment; that is, after all engineered process waste treatment and effluent controls have been effected. Contributing sources may also be monitored to permit easier identification of the sources of significant releases and to facilitate corrective measures at the proper locations. In those instances where liquid wastes are released on-site and may be subjected to additional on-site modification (e.g., dilution, decay, self-purification, decomposition) effluents are monitored at the point at which public access is no longer controlled, i.e., at the physical boundary of the site.

APPROVED BY

D SERIES
STANDARD PRACTICE PROCEDURE
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

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SUBJECT: WASTE MANAGEMENT AND ENVIRONMENTAL POLLUTION CONTROL R

5-15.5 c. MONITORING: (Continued)

Environmental measurement locations are determined by the location of population centers, probable points of maximum and average concentrations, critical pathways in the environment, and requirements for base line or background data. The extent of coverage is based on hazard potential, type of material released, quantities and concentrations of materials released, specific local public interest or concern, and the extent and type of utilization of affected off-site air, land, and water.

d. Type and Frequency of Sampling. Sampling frequency and type are determined by considering the purpose(s) for which the data are being obtained and the chemical and physical parameters of the pollutants involved, i.e., evaluation of the effectiveness of waste treatment and control, compliance with applicable standards, reconcentration factors in the environment, pollutant half-life, and exposure mode.

Gross radioactivity measurements are appropriate only when specific radionuclide concentrations are very low or when it is impossible or impractical to identify or estimate specific radionuclide concentrations by other measures.

e. Monitoring Data Record-Keeping. The flow rate and the specific pollutant concentration in each effluent stream are determined and recorded in the units in which the standards are expressed. Descriptive information regarding the physical and chemical form of the radionuclide or pollutant, detection limits, points of release, receiving streams and other pertinent descriptive information are included as necessary to interpret the data.

5-15.6 CONTROL:

a. Effluents. Each liquid and gaseous effluent stream is examined with a view toward reducing the quantities of pollutants discharged to the lowest practicable levels.

Emphasis is placed on those measures which will result in the greatest reduction in the quantity of material being released. Primary attention is given to those materials which tend to persist in the environment and/or are of greater biological significance including all transuranic elements and specific elements such as Strontium 90, Cesium 137, Cobalt 60, etc.

b. Solid Waste Burial Sites (Radioactive). Each installation maintains a map of burial sites and a record of available information on the kind and quantity of materials buried in each trench or grave. Each site is periodically monitored to determine the adequacy of effluent containment.

c. Disposal of Solid Waste (Other Than Radioactive). Waste disposals must be controlled within the established standards shown in AECM Appendix 0510 and other applicable Federal, State and plant regulations.

5-15.7 REPORTING REQUIREMENTS: The Environmental Control Coordinator at each installation will coordinate the preparation of reports as required by the AEC or UCC-ND Management. Each report will be submitted to the Office of Safety and Environmental Protection for review, evaluation, and submission to the AEC.

5-15.8 PROCEDURE: Procedural statements, if required, are contained in the installation supplement to this procedure.

APPROVED BY Lloyd L. Culler, Jr.

ORNL SUPPLEMENT
D SERIES
STANDARD PRACTICE PROCEDURE
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

NUMBER	D-5-15
DATE	September 14, 1973
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SUBJECT: WASTE MANAGEMENT AND ENVIRONMENTAL POLLUTION CONTROL N

5-15.2 RESPONSIBILITIES:

a. Each Division:

1. Identifies all of its potentially significant pollution sources, informs the Installation Environmental Control Coordinator of these sources and arranges with him to establish necessary monitoring systems for the gaseous and liquid effluents from those sources.

2. Takes immediate remedial action to correct adverse trends in environmental quality resulting from its operations.

3. Ascertains that employees are familiar with established Standard Practice Procedures relating to all aspects of effluent control applicable to the functions for which they are responsible.

4. Reviews operating practices to determine if operating procedures can be revised to reduce or control emissions.

5. Initiates studies for resolution of pollution problems where the nature of the effluents and quantities involved indicate problems that cannot be resolved by revising operating procedures.

6. Informs the Installation Environmental Control Coordinator of planned new projects or modifications to existing facilities which could effect environmental quality.

b. Health Division, Industrial Hygiene Department:

1. Defines the limits for nonradioactive contaminants in effluents to assure total compliance with pollution control regulations as referenced in this procedure.

2. Measures the quantities and/or concentrations of nonradioactive pollutants in various environmental media which may result from airborne or liquid effluent releases, maintains adequate data records and reports these data to Laboratory Management and the Laboratory Environmental Control Coordinator.

3. Determines, with the assistance of the Laboratory Environmental Control Coordinator, the nonradioactive pollutants to be monitored in effluents and environmental media and the location and frequency of measurements.

4. Prepares periodic analysis reports on nonradioactive, environmental pollution as required by UCC-ND Management and the AEC.

c. Health Physics Division, Radiation Monitoring Section:

1. Defines the limits for radioactive contaminants in effluents to assure total compliance with pollution control regulations as referenced in this procedure.

3/6/75 – Copy provided for ORNL Report
CF-75-2-23 (Julian Gissel)

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2. Measures the quantities and/or concentrations of radioactive pollutants in various environmental media which may result from airborne or liquid releases, maintains adequate data records and reports these data routinely to Laboratory Management and the Laboratory Environmental Control Coordinator.

3. Determines, with the assistance of the Laboratory Environmental Control Coordinator, the radioactive pollutants to be monitored in the effluents and environmental media and the location and frequency of measurements.

4. Prepares periodic analysis reports on radioactive, environmental monitoring as required by UCC-ND Management and the AEC.

d. Installation Environmental Control Coordinator:

1. Coordinates the Laboratory's pollution abatement and monitoring programs. Serves as liaison between the various ORNL groups involved in pollution control, ORNL Management, and UCC-ND Office of Safety and Environmental Protection.

2. Determines, with the assistance of the Health Physics Division and the Health Division, the pollutants to be monitored in effluents and environmental media and the location and frequency of the measurements.

3. Identifies areas where development work, additional monitoring equipment and changes in waste disposal practices are required for pollution abatement.

4. Maintains adequate records on significant effluents within the installation.

5. Reviews or provides for review of the design, acquisition and installation of required pollution control equipment.

6. Coordinates and expedites the preparation of analytical reports on the Laboratory's effluents and environmental monitoring as required by UCC-ND Management and the AEC.

e. Environmental Sciences Division:

1. Receives information from the Laboratory Environmental Control Coordinator on proposed projects which may have a significant effect on the environment and advises him as to the nature and extent of the potential environmental impact of the proposed project or the need for considering various alternatives before proceeding with the work requested.

2. Prepares and/or assists in preparing environmental impact statements for projects initiated by other divisions as requested by those divisions.

f. Operations Division:

1. Monitors radioactive and nonradioactive pollutants in final effluents and internal waste streams as directed by the Laboratory Environmental Control Coordinator.

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2. Routinely reports internal monitoring and effluent discharge data to ORNL Management, Laboratory Environmental Control Coordinator, Health Physics Division, Health Division, and divisions responsible for the discharges.

3. Prepares periodic analysis reports on radioactive and nonradioactive effluents as required by UCC-ND Management and the AEC.

g. Plant and Equipment Division and Engineering Groups:

1. Inform the Laboratory Environmental Control Coordinator of all regular and blanket work orders received for projects which may have a significant effect on the environment and obtain his approval of the projects before proceeding with the work requested. These projects will include design and/or construction of new process equipment which may release pollutants into the air and surface streams, landscaping and earth moving work which may pollute streams, and work on White Oak Creek and its tributaries which change the course of those streams.

APPENDIX B

ORNL HEALTH PHYSICS MANUAL, CHAPTER 5.1
DISPOSAL OF SOLID RADIOACTIVE WASTES

Number	5.1		
Page	1	of	8 Pages
Issued	3/14/74		
Supersedes Issue Dated	10/19/70		

DISPOSAL OF SOLID RADIOACTIVE WASTES

POLICY

It is the policy of the Oak Ridge National Laboratory to dispose of solid radioactive waste by land burial or to store fissile alpha solid wastes in a retrievable state in approved storage areas. The handling, collection, disposal, and storage operations are to be in compliance with the Code of Federal Regulations, AEC Manual Chapters, and Laboratory procedures.

DEFINITIONS

For disposal purposes, solid radioactive wastes at ORNL are divided into four categories: general radioactive waste, fissile alpha waste, fissile non-alpha waste, and mixed waste.

1. General Radioactive Waste - Solid waste which is neither "fissile alpha" nor "fissile non-alpha" as defined below. In general, this waste will contain beta-gamma activity and/or non-fissile alpha activity (such as Po, Th, Ra, ^{232}U, etc.). For disposal purposes, general radioactive waste is divided into two categories: low-level radioactive waste and high-level radioactive waste.

   (a) Low-Level Radioactive Waste - General radioactive waste packaged in an approved container with the transferable contamination on the outer surface meeting the requirements of Procedure 4.1 of the Health Physics Manual and where the radiation reading at contact with the outer surface of the package is less than 200 mR/hr.

   (b) High-Level Radioactive Waste - Same as the low-level radioactive waste except that the radiation reading at contact with the outer surface of the unshielded package exceeds 200 mR/hr.

2. Fissile Alpha Waste - Solid waste which exceeds a concentration of 10 μCi/kg of alpha activity which is associated with fissile isotopes. This includes the trans-uranium isotopes and ^{233}U.

3. Fissile Non-Alpha Waste - Solid waste which contains one gram or more of essentially non-alpha emitting fissile isotopes (normally ^{235}U) regardless of concentration or which exceeds a concentration of 1 gram of the fissile material per cubic foot regardless of the amount.

4. Mixed Waste - Solid waste containing two or more of the above three types of radioactive waste.

The methods of handling waste are considered as either routine or nonroutine.

1. Routine Handling - This method of handling involves the various operations that are outlined in standard operating procedures.

2. Nonroutine Handling - This method involves operations that cannot be done according to standard operating procedures and require special arrangements.

LIMITATIONS

This procedure applies to disposal of solid radioactive wastes only. Burial of liquid waste must be approved by Laboratory Protection and Safety.

RESPONSIBILITIES

1. Supervision

   (a) Sees that all employees who have occasion to dispose of general radioactive wastes and wastes containing fissile or fissile alpha material are properly instructed in the requirements of this procedure and other procedures and precautions which may enhance the safety of disposal operations.

   (b) Sees that necessary solid radioactive waste storage-pickup stations are established for areas producing such waste and sees that each station is properly designated and zoned in accordance with Procedure 2.7 of the Health Physics Manual.

   (c) Provides approved storage containers and miscellaneous supplies (polyethylene bags, masking tape, etc.) at each storage-pickup station.

   (d) Sees that solid radioactive wastes for disposal are properly segregated, treated, and/or packaged to contain loose materials and transferable contamination before being deposited in approved secondary containers.

   (e) Sees that each container of solid radioactive waste is properly surveyed, inspected, and tagged with a "Radiation Hazard" (UCN-2785) tag before its release from the local storage-pickup area.

   (f) Periodically inspects the waste containers for serviceability and disposes of them when they are no longer suitable for use.

   (g) Sees that appropriate radiation surveys and inspections are made of storage-pickup areas and that corrective action is taken when faulty practices and/or excessive levels of radiation or contamination are noted.

(h) Informs the Solid Waste Storage (SWS) area foreman in advance (four hours, if possible) of any contemplated nonroutine disposal operations.

(i) Initiates form UCN-2822 (Fig. 1) when disposing of other than low-level radioactive wastes. If hazardous materials such as Hg, NaK, Na, Li, PCB's, etc., are to be included in the disposal operation, these are to be noted on the form with any special instructions and/or recommendations regarding the handling and burial of such items.

(j) Initiates form UCN-5917, "Request for Nuclear Safety Review", for Criticality Committee approval if the waste content exceeds 1 gram of fissionable material per cubic foot.

(k) Obtains approval, in writing, from Laboratory Protection and Safety for consignment to the SWS area of fissile alpha and fissile non-alpha wastes not requiring a nuclear safety review.

(l) Satisfies the requirements of the S. S. Accountability Office for the disposal of SSN material. This requires the initiation of form UCN-2681, "Record of SSN Transaction."

2. Operations Division

(a) Aids area supervision in establishing storage-pickup stations and provides appropriate schedules for pickup of low-level radioactive wastes.

(b) Provides containers where needed for waste storage-pickup stations.

(c) Picks up, or arranges for the transportation of, waste from the storage-pickup stations to the disposal site, assuming responsibility at the pickup point. Sees that all solid radioactive waste packages have been surveyed for radiation hazards before truck loading and transporting within the Laboratory premises and during transfer from trains or other commercial carriers at the SWS area.

(d) Assures that waste containers are stored in a safe manner considering fire, tornadoes, and other hazards.

(e) Coordinates assistance required for waste handling and disposal operations.

(f) Provides and ensures, within SWS area, the use of appropriate protective equipment, Contamination Zone clothing, monitoring devices, change facilities, and other supplies necessary for the control of personnel exposure and the prevention of spreading of radioactive contamination.

(g) Provides necessary access controls to Laboratory SWS areas.

(h) Is responsible to see that a permanent file of engineering survey data regarding outer boundary lines of each SWS area is maintained.

(i) Maintains adequate records of all disposals and of all storage locations.

3. Health Physics

   (a) Formulates and recommends health physics standards and specifications for the handling, monitoring, disposal, and storage of all solid radioactive wastes.

   (b) Provides consultation, monitoring, and other health physics services for disposal and storage operations and for the evaluation of possible waste movement within and from burial areas.

   (c) Assists in the preparation of form UCN-2822 (Fig. 1).

   (d) In conjunction with Laboratory Protection and Safety, evaluates solid waste disposal operations and new solid waste disposal facilities.

4. Environmental Sciences Division

   (a) Determines radioactivity movement from SWS areas and recommends methods for stopping or preventing this movement.

   (b) Evaluates proposed disposal areas from the standpoint of environmental, geological and hydrological adequacy.

REGULATIONS

Comprehensive

1. Disposal and storage sites shall be selected with the advice and approval of Environmental Sciences and Health Physics and in accordance with geological and hydrological criteria.

2. Solid radioactive wastes shall be stored or disposed of only in established storage and burial areas and in accordance with approved procedures.

3. Solid radioactive waste originating within the Laboratory, or accepted from other installations, shall be handled on a current basis and shall not be allowed to accumulate excessively.

4. Solid radioactive wastes shall be handled and disposed of in a manner that will preclude the likelihood of fire, explosion, and/or a toxicity hazard.

5. Loose radioactive material shall be contained and transferable contamination made nontransferable insofar as is practical by packaging or other approved means before wastes are released for burial.

6. Radioactive wastes requiring radiation shielding (such as a lead cask) for safe transfer to the SWS areas shall be considered as an operation requiring nonroutine handling.

That is, disposals of this nature must have the prior approval of SWS area supervision.

7. Radiation surveys shall be performed by Health Physics prior to pickup of solid waste for burial or storage.

8. Remote handling devices, special shielding, and other protective equipment shall be utilized as required to minimize personnel exposure during waste handling and disposal operations.

9. Beds of carrier vehicles shall be made leakproof for contamination control and equipped with adequate shielding between the cab and truck bed for personnel exposure control.

10. Carrier vehicles will be routed so as to offer the least hazard to Plant personnel and interference with other Laboratory operations.

11. Personnel handling radioactive waste shall at all times wear their identification film badges and any other personnel monitoring meters that may be required and specified by Health Physics.

12. After each burial or storage operation, the personnel, equipment, waste containers, and vehicles involved shall be checked for contamination and decontaminated as required.

13. Monitoring shall be performed as required both within and adjacent to each burial area to ensure the integrity of disposal operations.

14. Access to SWS areas shall be limited to personnel authorized by SWS supervision.

15. Disposal of large volumes of waste such as contaminated earth, building materials, large equipment items, etc., shall be considered as an operation requiring non-routine handling. Disposals of this nature must have approval of the Operations Division with concurrence of Laboratory Protection and Safety.

16. The advance approval of Health Physics and Laboratory Protection and Safety shall be required for the disposal of any solid radioactive wastes by incineration.

17. Classified burials must be approved by Laboratory Protection and Safety.

General Radioactive Wastes

Approved containers located at designated storage-pickup stations for general radioactive wastes shall be yellow in color, leakproof, and equipped with tight-fitting covers. These containers should be fitted with a plastic liner before any radioactive material is placed in the can. When the contents of a container are ready for pickup by SWS area personnel, the plastic liner should be tied securely prior to placing the cover on the container. If the plastic liner can be damaged or broken, the cover should be taped to the container and the container buried.

Fissile Alpha Waste

1. Normally, when radiation levels at the surface of the containers will permit, fissile alpha waste shall be stored in one of the five types of containers listed below. The amount of fissionable isotopes permitted in each container is also shown. The average fissile alpha content may not exceed 5 g/cu ft nor may the total fissile alpha content per container exceed 200 grams.

Type of Container	Max. Amount of Fissionable* Material
30-gallon drum (stainless steel)	20 grams
55-gallon drum (stainless steel)	36 grams
Concrete cask (thin wall) Outside dimensions - 51" OD x 7' Inside dimensions - 42" ID x 6'1"	200 grams
Concrete cask (thick wall) Outside dimensions - 51" OD x 7' Inside dimensions - 27" ID x 4'10"	96 grams
Concrete cask (intermediate wall) Outside dimensions - 54" OD x 7'3" Inside dimensions - 42" ID x 6'1"	200 grams

*In this context, the term fissionable applies to the isotopes ^{233}U, ^{235}U, and ^{239}Pu.

The above containers are Stores stock items and may be obtained from the Solid Waste Storage Area, telephone 3-6356.

In those cases in which the above containers do not provide adequate shielding for the radioactivity to be transported and/or stored, other containers may be used subject to the approval of Solid Waste Storage personnel.

2. If at all feasible, burnable and nonburnable waste should be deposited in separate containers. If this cannot be done, the percentage of burnable material should be estimated and noted on the label. Containers must be labeled as follows: B (burnable, NB (nonburnable), or percent B.

Fissile Non-Alpha Waste

1. Solid waste containing fissile non-alpha isotopes will be disposed of by burial in an area specifically set aside for this purpose. Bulk quantities of fissile non-alpha waste, which normally would not include waste from cleanup operations or contaminated equipment, will be disposed of in auger holes. Location coordinates, including elevation, will be necessary for each such disposal. A maximum of 200 grams of fissionable material is permitted per hole. Auger holes must be spaced so that a minimum of three feet of earth exists between sides of adjacent holes. Holes are to be capped and marked.

2. Burials of all bulk quantities of fissile non-alpha wastes exceeding 1 gram of fissionable material per cubic foot must have the approval of the Criticality Committee. This requires the inititation of form UCN-5917, "Request for Nuclear Safety Review".

3. Form UCN-2681, "Record of SSN Transactions", is required before fissile contaminated waste is disposed of by SWS area personnel.

Mixed Waste

Disposal or storage of mixed wastes (two or more types of radioactive wastes as listed under Definitions) will be governed by the types of wastes contained within the mixture. The appropriate measures will be taken for each type of waste in the mixture.

Record Keeping

1. Storage records shall be maintained. In addition to the requirements of Health Physics Procedure 4.1, the receivers shall apply a permanent tag to each container, radiation level permitting, which is referenced to a computer log. When the radiation level is too great, the storage location (auger hole, etc.) shall be referenced.

2. The computer log for fissile alpha waste shall designate the Accountability Transaction Number, storage location, volume of waste, isotope(s) present, and amount (grams) of fissile alpha material. A monthly computer print-out shall be sent to Laboratory Protection and Safety.

3. The computer log for fissile non-alpha waste shall designate the Nuclear Safety Review Number, storage location, volume of waste, isotope(s) present, and amount (grams) of fissionable material. A monthly computer print-out shall be sent to Laboratory Protection and Safety.

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AUTHORIZATION FOR STORAGE OF RADIOACTIVE-CONTAMINATED SOLID WASTE

REQUESTER: EXECUTES THIS SECTION BEFORE ARRANGING MATERIAL TRANSFER

MATERIALS TO BE STORED

			ISOTOPES PRESENT AND AMOUNT (GRAMS)	
ORIGIN - BLDG.	SECTION OF BLDG.	TYPE OF CONTAINER	ATN	SNM
REMARKS			NSR	
☐ TRANSURANIUM	☐ FISSILE	☐ NEITHER		

TELEPHONE STORAGE AREA FOREMAN PRIOR TO MATERIAL TRANSFER (EXTENSION 3-6356)

REQUESTER'S AUTHORIZATION FOR DISPOSING MATERIALS	NAME		BADGE NO.	BUILDING	PHONE NO.
	DATE	DIVISION	DEPARTMENT		ACCOUNT CHARGE

HEALTH PHYSICIST: TO BE COMPLETED AT POINT OF ORIGIN OF SOLID WASTE AND BEFORE TRANSFER OF MATERIAL

RADIATION LEVEL

BETA-GAMMA SHIELDED, mrem@ inches; UNSHIELDED, mrem@ inches.

NEUTRON READING mrem/hr.

SURFACE CONTAMINATION - BETA GAMMA d/minute d/minute Alpha

HEALTH PHYSICIST MUST: ☐ ACCOMPANY SHIPMENT TRANSFER ☐ BE PRESENT DURING STORAGE

REMARKS

HEALTH PHYSICS APPROVAL FOR MATERIAL TRANSFER	NAME	DATE

STORAGE AREA: FOREMAN SENDS COPY TO ORIGINATOR AFTER STORAGE

REMARKS

TRENCH NO.	FFO	FFT		CF
WELL NO.	FFT			CF
BLDG. NO.	COMP. NO.	LEVEL		CF
SUPERVISOR'S RECEIPT OF MATERIALS	NAME	BADGE NO.	DATE	TIME

DISTRIBUTION: WHITE - STORAGE AREA FOREMAN
BLUE - RETURNS COMPLETED TO ORIGINATOR
CANARY - RETAINED BY ORIGINATOR

UCN-2822
(23 2-72)

Figure 1

APPENDIX C

ORNL HEALTH PHYSICS MANUAL, PROCEDURE 2.7
RADIATION CONTROL ZONES

Number 2.7
Page 1 of 6 Pages
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RADIATION CONTROL ZONES

POLICY

It is the policy of the Oak Ridge National Laboratory to maintain a program of continuous effort to reduce the spread of radioactive contamination by confining it to the smallest spaces possible and to establish zoned areas when the radiation dose rate or radioactive contamination level is such as to necessitate special controls.

DEFINITIONS

1. Radiation Zone - An area where control measures are established to prevent or minimize external radiation exposure to personnel.

2. Contamination Zone - An area where control measures are established to prevent the contamination of employees, the environs, and/or equipment and where there is the possibility that radioactive material may become deposited inside the body leading to internal radiation exposure.

3. Regulated Zone - An area where operations are restricted for the purpose of radioactive contamination control. This zone may contain Radiation Zones, Contamination Zones, or both, ranging in size from a small spot to a large area.

4. Zone Control Signs - Standard signs used for the purpose of identifying zone boundaries (see Procedure No. 2.3).

5. Contamination Zone Clothing and Equipment - Wearing apparel and equipment provided by the Laboratory for use in a Contamination Zone (see Procedure No. 2.11).

6. Zone Portal - A designated point on the boundary of a zone through which entrance to and exit from the zone should be made (see Procedure No. 2.9).

7. Contamination Zone Change Facility - A clothing change facility located within a Regulated Zone and/or adjacent to a Contamination Zone portal (see Procedure No. 2.10).

8. Contamination Zone Vehicle - A vehicle distinctly marked with Contamination and Regulated Zone signs and assigned for use in the transporting of contaminated materials or equipment within and/or between zoned areas. (R)

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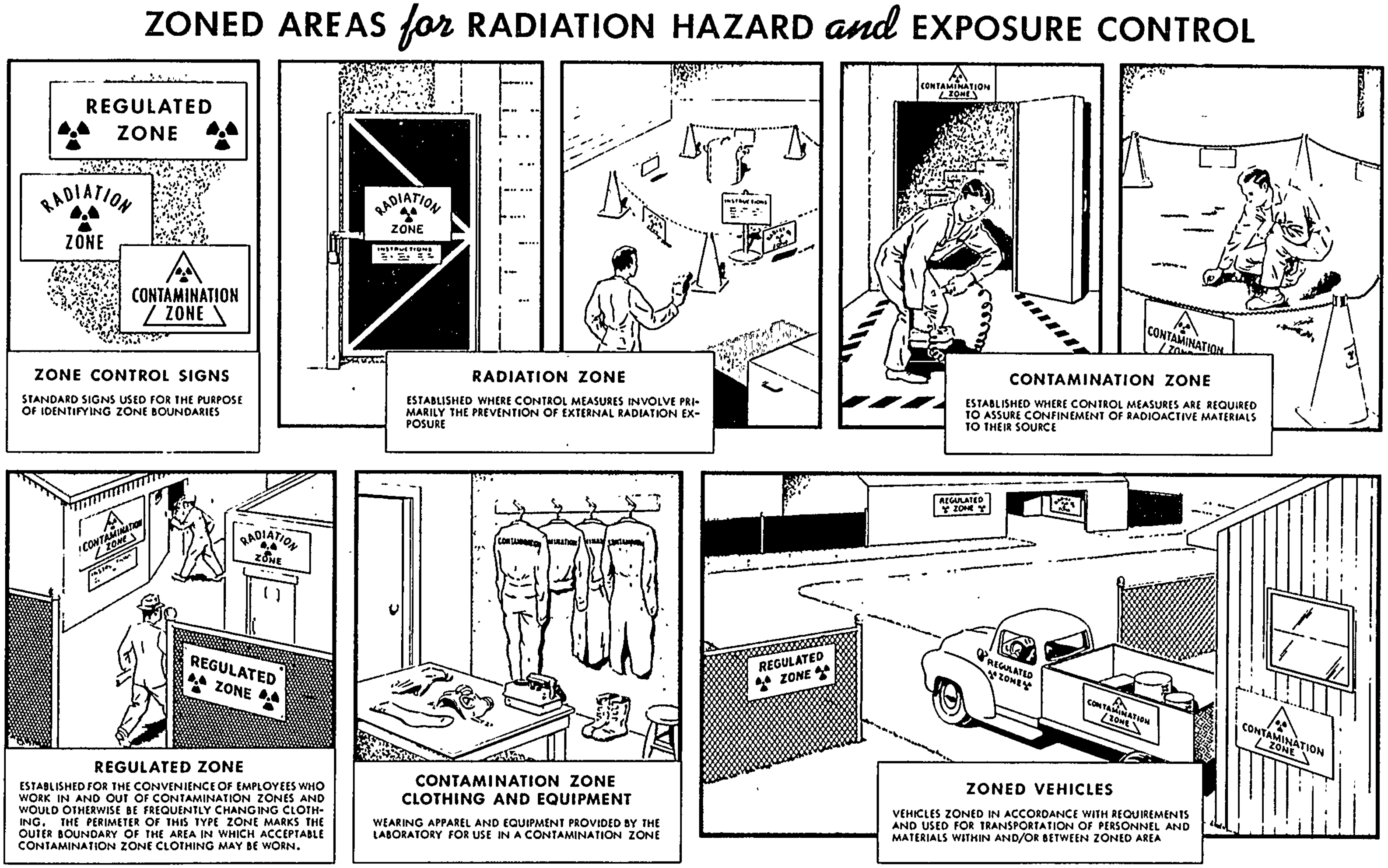

Fig. 1. Zoned Areas for Radiation Hazard and Exposure Control.

9. Transferable Contamination - Loose surface contamination that can be easily rubbed from the surface on which it exists or can be otherwise easily removed and transferred to other locations.

RESPONSIBILITIES

1. Supervision

   (a) Sees that all areas are surveyed by Health Physics as required and properly zoned as specified in this procedure.

   (b) Establishes appropriate physical boundaries and necessary portals for zoned areas (see Procedure No. 2.9).

   (c) Posts appropriate zone signs with up-to-date instructions pertaining to specific requirements associated with each particular zone.

   (d) Provides a suitable Contamination Zone change facility for Contamination Zone personnel with provisions for storage of personal effects where applicable.

   (e) Provides for a supply of required Contamination Zone clothing and equipment for Contamination Zone use.

   (f) Provides for necessary monitoring equipment at each Contamination Zone portal.

   (g) Provides necessary barricades, shielding, warning devices, contamination zoned vehicles, and other materials and equipment required for the administration of this procedure.

   (h) Establishes lunching facilities as required and in accordance with regulations specified by Health Physics.

   (i) Sees that all areas and operations under their supervision are released from zone status when zoning is no longer required.

2. Health Physics

   Provides adequate Health Physics services such as personnel monitoring, building and area surveys, exposure and survey records, consultation, and other assistance as required for the prevention of radiation exposures and for the administration of this procedure.

REGULATIONS

1. Each zoned area shall be defined and clearly marked with appropriate signs and may include a portion or all of a room, building, area, or vehicle.

2. Specific regulations governing a particular zone shall be posted at the zone portal or, when deemed more appropriate, in a conspicuous place immediately adjacent to each access point to the zone.

3. Only those persons authorized by supervision shall be permitted to enter the Radiation and Contamination Zones. (R)

4. Regulated Zones may be established in any area where operational procedures are such as to necessitate the simultaneous occupancy or use of Contamination Zone and non-Contamination Zone personnel and/or equipment. The Regulated Zone is accessible to all authorized personnel with restrictions only upon personnel and equipment entering from Contamination Zones as discussed in paragraph 8 below.

5. Radiation Zones shall be established when it becomes evident that personnel are being exposed to significant levels of ionizing radiation. Table 1 may be used as a guide for specific action.

Table 1. Guide for Establishment of Radiation Zones

Dose-Rate Range (rem/hr)	Immediate Action	Follow-Up Action
0.003-0.006	Post low-level tags if the accumulated daily dose to personnel may be 20 mrem	Periodic Review
0.006-1	Post warning signs or tags	Rope off the area if the accumulated weekly dose may be 1 rem
1-3	Post warning signs or tags; rope off	Erect a barricade which provides absolute exclusion of personnel. If the accumulated weekly dose in the area may be 12 rem, lock or block entrance
Over 3	Post warning signs and tags and erect barricades; lock and/or block all entries	

6. Persons entering Radiation Zones will be provided with special instrumentation and Health Physics surveillance as required. Where the dose rate is significantly high special administrative approvals may be required. Table 1, "Guide for Planning

and Authorizing Exposure to Specified Dose Rates", Procedure No. 3.2, will be used in the establishment of requirements for entry into Radiation Zones.

7. Contamination Zones shall be established for a designated area when it becomes evident that personnel and equipment within it and the environs surrounding it are subject to becoming significantly contaminated with radioactive materials. Table 2 shall be used as a guide in the establishment of Contamination Zones. If the specific contaminants are known, the values listed in Table 2 may be adjusted by Health Physics in accordance with established practices.

Table 2. Guide for Establishment of Contamination Zones

Establish Contamination Zone when the limits listed below are exceeded:

Type of Radiation	Airborne Contamination (μCi/cc air)	Direct Reading Surface Contamination	Transferable Surface Contamination (d/m/100 cm²)
Alpha	2×10^{-12}	300 d/m/100 cm²	30
Beta-Gamma	3×10^{-10}	0.25 mrad/hr	1000

NOTE: The alpha surface contamination levels given above are maximum values and are derived primarily to serve as a guide where the contamination involves a small area such as a single room or cell. When the contamination is extensive and involves radionuclides such as ^{239}Pu or some other long-lived α emitter of comparable toxicity, the alpha levels permitted should average no more than 1/10 of the above values. More detailed information regarding Contamination Zones and Contamination Zone controls is given in Procedure No. 2.5, Appendix A-3, and in various sections of Appendix A-2.

8. Entrance to and exit from a Contamination Zone will be made through specified portals, except when the Contamination Zone is limited to the confines of a Contamination Zone vehicle, in which case the regulations applicable to a Contamination Zone vehicle will apply. Persons entering Contamination Zones will be provided with special instrumentation, protective equipment, and Health Physics surveillance as required. Personnel and/or equipment are authorized to leave a Contamination Zone only when proved free of transferable contamination by approved monitoring techniques.

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9. Contamination Zone clothing and/or equipment will not be used outside a Contamination Zone or a Regulated Zone except when used in conjunction with a Contamination Zone vehicle following a prescribed route.

10. No lunchroom or lunching facility will be established within a Contamination Zone.

11. Storage or preparation of food and beverages, eating, smoking, and drinking are prohibited in Contamination Zones except drinking from approved water fountains.

APPENDIX D

HEALTH PHYSICS MANUAL, PROCEDURE 2.4
SOURCE, SPECIAL NUCLEAR, AND SPECIAL MATERIALS CONTROLS

SOURCE, SPECIAL NUCLEAR, AND SPECIAL MATERIALS CONTROLS
(From ORNL SPP Number 31-D, Rev. May 31, 1961)

POLICY

It is the policy of the Laboratory that source, special nuclear, and certain special materials be made available to employees only as required for authorized operations or experiments; that such materials be handled in accordance with related regulations and that, wherever feasible, independent measurement determinations be made to ensure proper control.

DEFINITIONS

(a) Source Material - Any material, except special nuclear material, which contains by weight one-twentieth of one percent (0.05 %) or more of (1) uranium, (2) thorium, or (3) any combination thereof.

(b) Special Nuclear Material - (1) Plutonium, uranium-233, uranium enriched in the isotope 233 or in isotope 235, and any other material which the AEC, pursuant to the provisions of Section 51 of the Act (Atomic Energy Act of 1954 as amended), determines to be special nuclear material, but does not include source material; (2) any material artifically enriched by any of the foregoing, but does not include source material. 7

(c) SS Material - This term is used for accountability purposes. It includes both source and special nuclear materials as defined above, and other materials such as neptunium-237, materials enriched in lithium-6, deuterium, and tritium. The SS Materials Accountability Representative should be contacted when information on SS materials is required.

(d) Routine Analysis (for purposes of this procedure) - An analysis having no significant bearing on SS material balances.

(e) Special Analysis - An analysis performed for verification of inventory or material balance, material content being shipped from the Laboratory or received from other installations.

(f) SS Materials Accountability Office - Initiates procedures and supervises, in accordance with existing AEC regulations, the source, special nuclear, and special materials program at the Laboratory, especially in regards to: forecasting, transfers, outside shipments, requests for materials, surveys, inventories, accounting, etc.

(g) Balance Area Representative - An employee appointed by his Division Director to administer the SS Materials Program within an assigned division area.

(h) Criticality Committee - A committee established by Laboratory Management to review and approve criticality safety in shipping, receiving, handling, storage, and usage of Special Nuclear Materials, and to inform supervision of its findings.

LIMITATIONS

(a) All SS materials located in the ORNL X-10 Area shall be accounted for through the ORNL SS Materials Accountability Office, Facility FZC. All materials located in the ORNL Y-12 Area shall be accounted for through the Y-12 Uranium Control Department, Facility FZB. Laboratory personnel located at Y-12 shall adhere to Y-12 procedures relative to SS Accountability.

(b) Transfers between installations are prohibited unless approved by the AEC and effected between the installations accountability offices.

RESPONSIBILITIES

(a) Balance Area Representatives shall supervise and record all transactions involving SS materials in their balance area, and in accordance with requests of the SS Materials Accountability Office.

(b) SS Materials Accountability Office shall be responsible for overall administration of items outlined in Definitions (f).

(c) Analysis Requesters shall determine whether an analysis is to be considered routine or special and request such as indicated under Analytical Request on page 5.

(d) Analytical Laboratory Supervisors shall ensure that crossover of assay or different types of SS material is prevented when unused portions of samples are retained and stored in waste carboys for recovery purposes.

(e) The Criticality Committee shall:

(1) Approve all shipping containers, storage containers, and physical arrays used for special nuclear materials exceeding the limits of Part (c) below.

(2) Approve the design and proposed operation of all processes and equipment for quantities of special nuclear materials exceeding the limits of Part (c) below.

(3) Annually survey and review each balance area holding quantities equal to or greater than those listed in Part (c) below.

REGULATIONS

(a) At no time shall SS materials be removed from the ORNL X-10 Area unless coordinated through the SS Materials Accountability Office.

(b) All requests for Criticality Committee services shall be in writing and directed to the chairman of the Committee.

(c) Approval must be obtained from the Criticality Committee (Nuclear Safety Review Request) prior to the receipt of fissile materials for any operation if the following listed amounts are to be exceeded.

(1) 200 g ^{235}U or ^{233}U or mixtures thereof, but excluding the ^{235}U in items of natural or depleted uranium, or

(2) 200 g of the sum of the elements Pu, Np, Am, Cm, Bk, and Cf, or

(3) 5 g of the sum of the isotopes ^{236}Np, ^{242m}Am, ^{243}Cm, ^{245}Cm, ^{247}Cm, ^{249}Cf and ^{251}Cf.

(d) To avoid exceeding the quantities listed in Part (c) above, each new material request shall show the quantity on hand in addition to the amount requested.

(e) No internal transfers shall be made until it is established with the receiver and the SS Materials Accountability Office that the materials on hand plus the material to be transferred will not cause the receiver's inventory to exceed the amount listed in Part (c) above. (See also, SS Accountability Procedures, Intra-Laboratory Transfers, Page 5 of this Procedure.)

(f) All ORNL operating and storage areas shall be monitored periodically by Health Physics for determination of radiation and contamination levels.

(g) Health Physics surveys shall be made on all items of SS materials received or shipped and appropriate warning tags affixed indicating the hazard.

(h) Each package of SS materials shipped to a destination outside the ORNL X-10 Area shall be packed and shielded in a manner which conforms with all Federal regulations. (See also, SS Accountability Procedures, Shipping, Page 5 of this Procedure.)

(i) All SS and special materials shall be stored and safeguarded in accordance with the Physical Security Standards outlined in the AEC Manual, Chapter 2401, and the related AEC Appendix 2401-07, A through F. A copy of these standards is maintained in the SS Materials Accountability Office and the Laboratory Protection Division Office.

(j) Storage and use of strategically important materials of a security interest in non-security areas must have prior approval of the ORNL Security Department, which will review the location and storage facilities to ensure compliance with all current AEC security regulations.

SS ACCOUNTABILITY PROCEDURES

ANALYTICAL REQUESTS

Routine Analysis -

a. Form UCN-1910, Request for Control Analysis, is completed in duplicate to request routine analysis. One copy is forwarded to the Analytical Laboratory along with the sample.

b. Analysis results are reported to the requester on the first copy of form UCN-2134, Analytical Data Report.

Special Analysis -

a. Form UCN-3709, Request for Control Analysis, is completed in triplicate. Copies one and three are forwarded to the Laboratory with the sample.

b. Analysis results are reported to the requester on the first copy of form X-494, Analytical Data Report. The second copy is sent to the SS Materials Accountability Office.

NOTE: Transfer of a sample weighing 50 mgs or more of special nuclear material for analysis shall be reported to the SS Materials Accountability Office on form TX-4342, Source, Nuclear, and Special Materials Transfer.

DISCARDING ECONOMICALLY UNRECOVERABLE MATERIALS

a. SS materials may be removed from inventory only upon an approved recommendation of the SS Accountability Representative.

b. A request of discard is made on form UCN-6073, Request for Authorization to Dispose of SS Material, to the SS Materials Accountability Office.

c. As soon as approved, the SS Materials Accountability Office notifies the requester in writing of the disposition of the SS materials in question.

d. Discard normally will be made to the burial ground with form TX-4342, Source, Nuclear, and Special Materials Transfer, being used to record the transfer. All pertinent data, such as analytical measurements, the gross, tare, net, and SS net weights shall be shown on the transfer along with exact location of burial. The transfer should also show a cross reference to the approval for discard.

DISPOSITION OF RESIDUES AND UNUSED PORTIONS OF SAMPLES AFTER ANALYSIS

a. Residues and unused portions of original samples consisting of less than 50 mgs of fissionable element material are returned to the analyses requester or placed in a waste carboy for recovery purposes as considered appropriate by the Analytical Laboratory Supervisor. Final disposition must be entered at the bottom of the Analytical Data Report Sheet.

b. Residues and unused portions of original samples consisting of more than 50 mgs of fissionable element material, if returned to the requester, are accompanied by form TX-4342, Source, Nuclear, and Special Materials Transfer. If retained in the Laboratory, accountability for the material remains with the Analytical Laboratory Supervisor.

c. Accumulated waste should periodically be turned into the SS Materials Accountability Office for return to reprocessing channels.

FORECASTING

a. The SS Materials Accountability Office shall notify Division Directors by memo when forecasts are required.

b. Divisions requiring SS materials or special materials and/or having such materials to return to production channels should forward to the SS Materials Accountability Office forecasts of their requirements and/or returns.

INTRA-LABORATORY TRANSFERS

a. All intra-laboratory transfers are coordinated through both Balance Area Representatives. A list of representatives is published and issued by the SS Materials Accountability Office.

b. The transferor completes form TX-4342, Source, Nuclear, and Special Materials Transfer, which is signed by both the sending and receiving Balance Area Representatives.

c. SS materials received by transfer between balance areas shall be measured by either the shipper, receiver, or both. In event a measurement is impractical, the reason must be shown on the transfer form.

d. Transfer of SS materials to the Tank Farm must be measured by the sender.

e. All transfers of special materials must be recorded on form UCN-7052, Special Reactor Materials Transfer.

PHYSICAL INVENTORIES

a. Individuals holding SS materials must maintain a currently valid list of all items in their possession and must keep the Balance Area Representative properly informed concerning the status of materials. Whenever feasible, the material should be labeled with inventory tags.

b. Physical inventory, where practicable, shall be taken the first day of each month (see exceptions in d below) and results immediately reported to the Balance Area Representative on form UCN-2676, Monthly Inventory Work Sheet. Reference should be made to current weighings, mass assays, and analysis which improve or substantiate previous estimates or inventories. All inventory variations shall be fully explained to the SS Accountability Office.

c. Balance Area Representatives consolidate individual reports and forward results to the SS Materials Accountability Office on form UCN-3687, SS Material Inventory and Calculations Sheet. Deuterium inventories are forwarded on form X-779, Deuterium Inventory List and Calculation Sheet.

d. Balance areas having small inventories of SS materials and/or inventories which include little turnover may, with prior approval, take inventories other than on a monthly basis.

e. Physical inventories of radium, zirconium, hafnium, beryllium, rare earths, or other government furnished materials are taken semi-annually at the end of June and December and results are reported on form UCN-4995, Inventory of Special Nuclear Materials.

f. When a discrepancy is discovered which cannot be attributed to normal loss resulting from research experiments, the SS Materials Accountability Office should be immediately notified.

g. To determine classification of SS inventory reports, they should be reviewed with the Associate Director of the Technical Information Division.

PROCUREMENT

Commercial - See SPP D-2-1, Part III of III, and ORNL supplement.

AEC Furnished -

a. The requester completes form UCN-2471, Request for SS Materials, and forwards it via his Balance Area Representative for concurrence of the Division Director.

b. Upon division approval, the request is forwarded to the SS Materials Accountability Office which obtains additional approvals as necessary and prepares the order for the materials.

c. Requests for radium, zirconium, hafnium, beryllium, rare earths, or other government furnished materials may be requested either by memo to the SS Materials Accountability Office or by Purchase Requisition.

QUALITY CONTROL FOR WEIGHING

a. Balance Area Representatives shall procure and maintain check weights to determine accuracy of scales (not analytical balances) used in weighing SS materials. Such checks are made before and after each weighing.

b. Records are maintained on each check weighing made, including quality control charts and these are reported to the SS Materials Accountability Office each month.

c. Weighing equipment will be checked every two weeks by the Fabrication Department of the Plant and Equipment Division. This Department will also repair and recalibrate defective weighing equipment and report results of their checking and repairing to the SS Materials Accountability Office, including variations from the Certified Bureau of Standards check weight.

RECEIVING

a. All SS materials received at Facility FZC shall be delivered to the SS Materials Accountability Office prior to issuance to balance area.

b. Receiving reports on SS materials resulting from direct purchase should be withheld until final weight determinations of material received have been made. Actual weight should be indicated on all copies of the Receiving Report (exception in c below).

c. When the seller indicates he does not guarantee the accuracy of material received in compound form, the receiving report should then be issued without delay.

d. SS materials received from other AEC facilities or sellers shall be measured and results reported to the SS Materials Accountability Office as soon as feasible following receipt of the material. Forms UCN-2143, Tally Sheet, and X-494, Analytical Data Report, are used in reporting.

SHIPPING

a. All shipments outside the ORNL X-10 Area are to be made by the SS Materials Accountability Office. This office also obtains special authority required from AEC to effect shipment.

b. When approval to ship is granted, the Balance Area Representative ensures that the material has been properly measured, packaged, and surveyed by a Health Physics Surveyor, before accountability is transferred to the SS Materials Accountability Office.

c. Shipment of Group I materials outside of the ORNL X-10 Areas are required to be escorted by an AEC Courier. This service is obtained through the SS Materials Accountability Office at the Laboratory Protection Division Office.

APPENDIX E

USAEC MANUAL, CHAPTER 0511
RADIOACTIVE WASTE MANAGEMENT

AND

USAEC-ORO MANUAL, CHAPTER 0511
RADIOACTIVE WASTE MANAGEMENT

U.S. ATOMIC ENERGY COMMISSION
AEC MANUAL

Volume: 0000 General Administration — AEC 0511-01
Part : 0500 Health and Safety — WMT

Chapter 0511 RADIOACTIVE WASTE MANAGEMENT

0511-01 POLICY

It is the policy of the AEC to manage radioactive waste in such a manner as to minimize the radiation exposure and associated risk to man and his environment over the lifetime of the radionuclides.

0511-02 OBJECTIVE

To assure safe long-term management of all radioactive waste generated by AEC operations and of that radioactive waste which is delivered to the AEC by licensed operations as required by regulations.

0511-03 RESPONSIBLITIES AND AUTHORITIES

031 The General Manager approves the AEC radioactive waste management plan submitted by the Division of Waste Management and Transportation (WMT) and determines compatibility of field office waste management plans with the AEC plan if questions as to compatibility raised by WMT are not resolved by the Assistant General Managers concerned.

032 The Director, Divsion of Waste Management and Transportation:

a. is responsible for program direction and fiscal control of the long-term management of high-level radioactive wastes at AEC facilities.
b. is responsible for program direction and fiscal control of all near-surface radioactive solid waste burial grounds at AEC facilities, and of engineered storage vaults at AEC facilities for interim storage of solid radioactive wastes from licensed activities.
c. is responsible for program direction and fiscal control of operations of Federal repositories for the disposal or long-term storage of radioactive wastes, to include: developing, performing studies for, designing, constructing, demonstrating, and obtaining necessary external reviews and approvals.
d. coordinates the development and annual updating of an overall plan for the management of radioactive waste from AEC operations.
e. calls for field office waste management plans, reviews them with advice of program divisions, and determines their compatibility with the overall plan.
f. exercises overall cognizance, coördination, and review of waste management activities, including the degree of progress in meeting schedules and objectives, to assure compliance with AEC policies and requirements; coördinates with appropriate program divisions to assure that field office waste management planning and budgeting are consistent with the AEC overall plan.
g. develops, recommends, and promulgates policies, guides, and requirements for treatment and storage of liquid, solid, and gaseous wastes at AEC facilities, including the definition of categories of waste; assists the Division of Operational Safety in the development of safety policies, guides, standards, and requirements for the release of radioactive effluents to the environment.
h. determines or approves criteria and specifications, including those relating to packaging and transport, for wastes which are to be stored in near-surface land burial grounds or engineered storage vaults at AEC facilities, or are to be stored in Federal radioactive waste repositories.
i. prepares in cooperation with appropriate field offices and contractor staff, environmental assessments and statements for major AEC waste management facilities, in accordance with IAD-0510-29.
j. maintains: (1) central records of the capabilities and capacities of AEC facilities and Federal repositories for accepting, processing, storing, burying, and disposing of radioactive waste; and (2) central inventories of radioactive waste being stored, buried, or disposed of at AEC facilities and Federal repositories.
k. provides program direction and fiscal control of a research and development program for

(1) techniques for long-term storage or disposal of commercial and AEC high-level waste; (2) compaction, incineration, or other improvements in handling practices for contaminated solid waste; and (3) improvements in air cleaning or liquid effluent treatment.

l. develops and defends budget estimates for its waste management responsibilities and activities, including facility requirements, and exercises fiscal control over such activities; provides staff assistance to other divisions in the budget submissions of waste management items for which they are responsible.

m. provides advice on applicability or interpretation of the provisions of this chapter and approves exceptions, where warranted, coordinating these actions with appropriate Headquarters divisions.

n. sponsors and coordinates testing and development of improved products and systems (such as High Efficiency Particulate Air Filters) for reducing to the lowest economically and technically practical[1] level radioactive material releases to the environment.

o. with regard to the above assigned responsibilities, acts as the General Manager's staff liaison and point of contact with the Office of Regulation and with other Federal, state, or local groups with regard to activities concerning (1) AEC-generated wastes and (2) commercially generated wastes to be delivered to the AEC as required by regulations.

033 The Director, Division of Operational Safety:

a. develops, recommends, and promulgates policy, standards, and requirements relevant to (1) the protection of man and the environment from radiation or contamination, and (2) safety of systems and system components used for controlling radioactive material discharge to the environment.

b. exercises overall surveillance, evaluation, and appraisal of AEC site effluent and environmental monitoring programs to assure compliance with AEC safety standards and policy relating to protection of man and his environment in accordance with AECM 0513. and coordinates such monitoring programs with comparable programs of other agencies.

c. in cooperation with WMT, evaluates radioactive waste management programs to assure that the AEC policy of controlling the release of radioactive materials to the lowest levels[2] technically and economically practical is being implemented.

d. appraises the safety aspects of field office waste managment programs and activities.

e. reviews waste management plans in relation to their impact on man and the environment and recommends any appropriate modifications to the Director, Division of Waste Management and Transportation.

f. coordinates with appropriate directors of program divisions prior to establishing policy standards which may have a programmatic impact.

034 Directors of Program Divisions, Headquarters:[3]

a. consistent with programmatic responsibilities and the provisions of sections 032 above and 044 below, provide direction of operations involving radioactive waste generated in their programs.

b. within programmatic responsibilities, may provide direction and guidance consistent with appendix part II for the preparation of waste management plans to be submitted by field office managers under 038(c).

c. review waste management plans submitted by field office managers relative to each site at which they have programmatic responsibilities, including related comments of other program divisions which have activities at those same sites, and consult with the Director, WMT, concerning his review function described in 032(e).

d. as requested by the Director, WMT, review inquiries on the applicability or interpretation of the provisions of this chapter and requests for exemptions.

e. consult with the Director, OS, in matters relating to policy, standards, and requirements relevant to the protection of man and the environment from radiation or contamination.

035 The Director, Division of Naval Reactors, assumes the same responsibilities as managers of field offices for its respective program activities.

036 The Director, Office of Information Services, assumes responsibilities for waste generated in connection with nuclear exhibits not under direction of any field office manager.

037 The Director, Division of Construction:

a. develops or approves in conjunction with WMT, and other concerned Headquarters divisions, design criteria for facilities to be constructed or modified for the purpose of processing or storing radioactive wastes or of controlling the release of radioactive wastes to the environment.
b. reviews waste management plans relative to their planned construction activities and advises the Director, Division of Waste Management and Transportation, on the estimated costs and schedules and conformance with design criteria.

038 Managers of Field Offices:

a. assure that the relevant criteria in 044, below, are followed in developing practices for routine and emergency operations at AEC installations under their jurisdictions and that current practices, where differing, are revised to comply with the criteria.
b. refer questions as to applicability, interpretation, or exemption from the criteria (see 044, below) to the Director, Division of Waste Management and Transportation, through the appropriate program divisions.
c. prepare and submit to WMT, with copies to the appropriate program divisions, annually updated waste management plans for their sites, following the general guidance in appendix 0511, part II.
d. maintain suitable approval control over key waste managment decisions of operating contractors, such as the establishment or major modification of:
   (1) operating limits for quantities or concentrations of radioactive materials released to the environment.
   (2) release locations and timing of releases.
   (3) methods of treatment of effluents to minimize release of radioactive materials.
   (4) methods of conversion of high-level liquid waste for interim storage or disposal.
   (5) process flowsheets, to the extent that they determine the quality or quantity of wastes.
   (6) methods of interim storage of solid wastes.
e. assure that for AEC operational situations, calculations related to burial/storage operations include full cost, exclusive of land, depreciation, added factor, and perpetual care costs. For purposes of comparative cost evaluations of solid waste burial or storage with and without additional processing for volume reduction, all costs are included, e.g., depreciation of facilities, cost of land, and present worth of perpetual care costs.
f. maintain records of radioactive waste stored or buried at their sites.
g. conduct a program of annual appraisals of contractor radioactive waste management activities.

0511-04 BASIC REQUIREMENTS

041 Applicability. This chapter applies to divisions and offices, Headquarters, field offices, and contractors who operate AEC-owned or -controlled facilities and whose contracts contain the Standard Safety, Health, and Fire Protection Clause (see AECPR 9-7.5006-47).

042 Coverage. This chapter and its appendix specify the responsibilities, requirements, and procedures which shall govern the management of radioactive waste.

043 Appendix 0511. Appendix 0511 contains definitions (part I) and guidance (part II) for use in implementing the policies and responsibilities of this chapter. The detail of the appendix is not to be taken as all-inclusive nor should it preempt the use of good judgment by knowledgeable field office and contractor staff in the development of safe practices and controls in the management of radioactive waste.

044 Operating Criteria. To assure an effective program for the management of radioactive waste, the following criteria shall be observed:

a. **General**
   (1) Field offices and their contractors shall conduct their operations and dispose of and store radioactive waste in such a manner as to assure that present and future radiation exposures to individuals and population groups will be at the lowest levels technically and economically practical not exceeding limits established in AECM 0524 appendix parts I and II.
   (2) Continuing efforts shall be made to develop and use improved technology for reducing the radioactivity releases to

the lowest technically and economically practical level.

(3) High-level liquid radioactive waste shall not be transported offsite.

(4) The extent and degree of radioactive contamination of land by AEC waste management activities shall be minimized.

b. **High-Level Radioactive Waste**

(1) High-level liquid wastes shall be converted to suitable physical and chemical forms and confined in a manner which shall provide high assurance of isolation from man's environment with minimal reliance on perpetual maintenance and surveillance by man under conditions of credible geologic, seismic, and other naturally occurring events.

(2) High-level liquid radioactive wastes may be initially stored in carefully engineered systems equipped with adequate provision for leak detection and control. Tanks and transfer systems shall be designed to resist credible internal and external forces. Technology shall be developed and employed as soon as practical to reduce the volume and mobility of the high-level liquid wastes placed in initial storage facilities.

(3) High-level liquid wastes in initial storage and high-level wastes in long-term storage, or in pilot plant facilities shall, in each case, be contained and emplaced so as to be retrievable for removal and transfer elsewhere. The method of storage and the physical and chemical forms of the stored waste shall be predicated on safety and not on possible retrieval for recovery of fission products for beneficial uses.

(4) The radioactivity and the chemical and physical characteristics of all high-level wastes in initial, long-term, or pilot plant storage shall be determined for each condition of storage.

(5) Spare tanks shall be maintained providing volume in excess of initial storage requirements for high-level liquid wastes. Each tank farm holding high-heat liquid waste shall have available, in tanks empty except for a residual heel, space equivalent to the largest volume of such wastes stored in any one tank. Each tank farm holding low-heat liquid waste shall have available reserve storage capacity to accommodate the contents of the largest tank in the system. Where interconnected tank farms are sufficiently close that the times required to transfer tank contents between farms are similar to the times required to transfer tank contents within a farm, such interconnected tank farms may be considered as a single tank farm for purposes of the above requirements.

c. **Other Liquid Radioactive Waste**

(1) Liquid radioactive waste not meeting the definition of "high-level waste" shall be converted into two fractions, one consisting of liquids which can be discharged to the environment pursuant to AECM 0524 (i.e., persons in uncontrolled areas will not be exposed to concentrations in excess of those prescribed in table II, annex A, appendix 0524) and the other consisting of either: (a) high-level liquid waste, which would be handled in accordance with the policies of b., above; or (b) solid waste which would be handled in accordance with the policies in d., below.

(2) As soon as technically and economically practical, the use of natural-soil columns (such as cribs, seepage ponds, and similar facilities) for liquid streams that exceed established standards for release of radioactivity to uncontrolled areas shall be replaced with other treatment systems. It should be recognized that liquid which meets established standards and is released to soil columns still may result in a buildup (at a slower rate) of radioactivity in the soil column. Thus, it would be advantageous to design soil column structures so either the soil can be retrieved and relocated or the points of release are separated to the extent that the buildup of radioactivity in the soil column will not exceed an acceptable level.

(3) Adequate diversion systems shall be provided to assure that normally releasable streams, which, as a consequence of accident or operational upset, exceed established standards (cited in AECM 0524) for releases to uncontrolled areas, are automatically

detected and diverted to controlled holding areas and are recycled or processed to yield a releasable stream.

d. **Radioactive Solid Waste Other Than That Generated by Solidification of High-Level Liquid Waste**
   (1) Technical and administrative efforts shall be directed toward a marked reduction of (a) the gross volume of solid waste generated in AEC operations and (b) the amount of radioactivity in such waste.
   (2) Volume-reduction technology, such as compaction and incineration, shall be adapted for use with radioactive solid waste and placed in operation wherever practical.
   (3) Except as dictated by (4), below, solid radioactive waste may be stored in conventional burial grounds approved by the AEC.
   (4) Solid waste generated at AEC sites and containing significant U-233 or transuranium nuclide contamination shall be stored at AEC sites, segregated from other radioactively contaminated solid waste and with combustible and noncombustible transuranium-contaminated waste packaged separately. The packaging and storage conditions shall be such that the packages can be readily retrieved in an intact, contamination-free condition for 20 years. The packages shall be suitably labeled so the waste they contain can be identified by cross-reference to permanent records.

e. **Airborne Radioactive Effluents.** Gaseous and other airborne radioactive effluents shall be controlled at the lowest level below the limits of AECM 0524 consistent with the state of the technology and good economic practices.

f. **Other.** Radioactive waste generated by underground nuclear tests, and remaining underground shall be considered as a special case.

045 References

a. AECM 2401, "Physical Protection of Classified Matter and Information," for additional protection required for classified radioactive waste.
b. AECM 0510, "Prevention, Control, and Abatement of Air and Water Pollution."
c. AECM 0513, "Effluent and Environmental Monitoring and Reporting."
d. AECM 0524, "Standards for Radiation Protection."
e. AECM 0529, "Safety Standards for the Packaging of Fissile and Other Radioactive Materials."
f. AECM 0530, "Nuclear Criticality Safety."
g. AECM 0544, "Planning for Emergencies in AEC Operations."
h. AECM 6301, "General Design Criteria."
i. AECM 7401, "Safeguards Control and Management of Nuclear Materials."
j. WASH-1202, "Plan for the Management of AEC-Generated Radioactive Wastes."
k. AEC Property Management Instructions Subpart 109-45.50, "Excess and Surplus Radioactively Contaminated Personal Property."

0511-05 NATIONAL EMERGENCY APPLICATION

In the event of a national emergency, as defined in AECM 0601-04, the provisions of this chapter and its appendix shall continue in effect.

[1] In the context of the policy statement in AECM 0524-012.

[2] In the context of the policy statement in AECM 0524-012.

[3] For purposes of this chapter, program divisions are those Headquarters divisions that provide functional direction of activities which generate radioactive waste.

d. For typical Pu-239 waste at this activity density, it is recognized that indirect measurements or estimates and administrative controls must be used instead of direct external measurements. An example of such administrative controls is the establishment of specific in-plant working areas from which typical wastes have been established by suitable studies as being either above or below the control value.

e. It is recognized that under present technology certain waste, primarily bulky discarded process equipment, with transuranium content above this value may not lend themselves to practical storage in full compliance with AECM 0511-044 d(4). However, these items should be recorded as transuranium wastes.

f. Requests for exception for applying the 10 nCi/g value on a package-by-package basis, with substitution of an equivalent quantity limit applicable to a burial facility, or requests for exemption for specific short half-lived transplutonium wastes, will be considered on a case-by-case basis, as per AECM 0511-032(m).

g. The 10 nCi/g value is a criterion for choosing different methods of handling different kinds of radioactive waste; it should not be confused with a value below which excess materials may be unconditionally released, as per AEC Property Management Instructions 109-45.50.

PART II

WASTE MANAGEMENT PLANS

A. PURPOSE

This part provides guidance on the development of a radioactive waste management plan for each site, as required by AECM 0511-038c.

B. DISCUSSION

Existing conditions at the various facilities will require different types and degrees of effort to meet the operating criteria of AECM 0511-044. Accordingly, the plans submitted under AECM 0511-038c need not be identical in degree of detail. Appropriate references to supplement or substantiate the information or conclusions stated in the plan should be provided. The outline of a waste management plan in C, below, is to be followed.

C. FORMAT FOR THE SITE WASTE MANAGEMENT PLANS

1. **Program Administration**

   1.1 Site
   1.2 Office Responsible
   1.3 Contractors
   1.4 Lead Responsibility for Site Plans
   1.5 Source of FY 1972 Funds for Waste Management

2. **Description of Waste Generating Processes**

   2.1 Process Flowcharts

3. **Description of Waste Management Facilities**

   3.1 Identification and Location of Facilities
   3.2 Description of Waste Treatment Facilities
   3.3 Description of Waste Storage Facilties
   3.4 Description of Effluent Control Systems
   3.5 Site Administrative Limits on Effluents

4. **Radioactive Waste Stored**

   4.1 High-Level Waste From Chemical Processing Operations
   4.2 Solid Radioactive Waste Other Than Solidified High-Level Waste
   4.3 Other Radioactive Materials

5. **Plans and Budget Projections**

   5.1 Interim Storage of High-Level Liquid Waste
      5.1.1 Milestone Charts
      5.1.2 Expected Accomplishments in FY 1972
      5.1.3 Proposed Program for FY 1973
      5.1.4 Proposed Program for FY 1974 and Beyond
      5.1.5 Five-Year Budget Projects for FY 1974 and Beyond
   5.2 Long-Term Storage of High-Level Waste
   5.3 Management of Low- and Intermediate-Level Liquid Waste
   5.4 Management of Solid Waste Contaminated With Radioactivity
   5.5 Management of Airborne Radioactive Waste
   5.6 Recapitulation of Budget Projection

Detailed Instructions for site waste management plans will be forwarded periodically to field office managers.

U. S. ATOMIC ENERGY COMMISSION
AEC MANUAL

Oak Ridge Operations Office

OR 0511

Volume: 0000 General Administration
Part: 500 Health and Safety

Chapter OR 0511 RADIOACTIVE WASTE MANAGEMENT

0511-03 Responsibilities and Authorities.

038 Managers of Field Offices.

a. Contract Administrators:

(1) Assure compliance with AECM and ORM 0511, and particularly AECM 0511-044, "Operating Criteria," in the management of any radioactive waste activities.

(2) Assure that contractors prepare and submit updated waste management plans for each site on an annual basis. These plans are to be submitted to the Research & Technical Support Division.

(3) Assure that contractors apply the provisions of AECM 0511 in all subcontract activities where radioactive waste is generated.

(4) Assure that contractors maintain updated records of radioactive waste stored or buried at their sites.

(5) Assure that cost calculations on burial/storage operations are performed as required in AECM 0511-038.e.

(6) Refer questions on applicability, interpretation, or requests for exemptions to the Research & Technical Support Division.

b. The Director, Research & Technical Support Division:

(1) Provides advice and assistance in the applicability, interpretation, or exemptions from the operating criteria of AECM 0511.

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(2) Requests advice and/or assistance from AEC Headquarters where appropriate in the application of the requirements of AECM 0511, especially in connection with proposed exemptions from the operating criteria.

(3) Maintains approval control over key waste management decisions in the establishment or the modification of the items specified in AECM 0511-038.d.

(4) Reviews and evaluates contractor waste management plans, and prepares the total OR plans for transmittal to Headquarters by the Manager.

(5) Participates in the annual appraisals of contractor radioactive waste management activities as appropriate from a programmatic standpoint in collaboration with the Safety & Environmental Control Division.

(6) Conducts programmatic reviews and evaluates radioactive waste management activities as required.

c. The Director, Safety & Environmental Control Division:

(1) Conducts annual safety and environmental protection appraisals of contractor radioactive waste management activities, as appropriate.

(2) Advises Contract Administrators of appraisals and makes recommendations for corrective actions, if appropriate.

(3) Evaluates, in cooperation with Research & Technical Support Division, radioactive waste management programs to assure that the AEC policy of controlling the release of radioactive materials to the lowest levels technically and economically practical is being implemented.

(4) Reviews waste management plans in relation to their impact on man and the environment and recommends to the Director, Research & Technical Support Division, any appropriate modifications.

HOISTING EQUIPMENT

A. Policy

It is the policy of the Oak Ridge National Laboratory to prevent personal injury and property damage by maintaining standards of safety consistent with national codes and standards in the design, procurement, installation, operation, maintenance, and inspection of hoisting equipment.

B. Definitions

Hoisting equipment includes powered industrial trucks; overhead and gantry cranes; crawler, locomotive, and truck cranes; derricks; elevators and accessories such as chains, hooks, slings, wire rope, and sheaves.

C. Responsibilities

1. Supervision is responsible for the overall safety of hoisting equipment under their jurisdiction. They shall ensure that all employees who operate, maintain or inspect such equipment are properly instructed and trained in the use of safe practices.

2. The Operator of a piece of hoisting equipment is responsible for operating the equipment in compliance with safe operating practices and for performing safety inspections as outlined in Table I of this procedure.

3. The Division Safety Officer is responsible for coordinating hoisting equipment safety within his division. He determines with the help of General Engineering, Plant and Equipment, and Inspection Engineering that all hoisting equipment is inspected, maintained, and operated in accordance with appropriate procedures.

4. The General Engineering Division is responsible for developing and maintaining standards for procurement, installation, and application of hoisting equipment.

5. The Plant and Equipment Division is responsible for scheduling and performing maintenance and effecting repairs as required on all hoisting equipment.

6. The Inspection Engineering Department is responsible for providing trained personnel, the necessary equipment, and performing inspections and tests as outlined in Table I of this procedure.

D. General Requirements

1. Each new or modified piece of hoisting equipment shall be surveyed by the General Engineering Division for compliance with recognized

standards. The equipment shall also be inspected and tested by the Inspection Engineering Department for the determination of safety prior to being placed in service.

2. Inspections shall be performed in accordance with Table I of this procedure.

3. Maintenance shall be performed in accordance with Plant and Equipment maintenance procedures.

4. Hoisting equipment not in service shall (1) be tagged out, (2) listed on the computer printout as "not in service", and (3) be given an appropriate inspection prior to return to service.

TABLE I

	Frequent	Periodic	Load
Overhead & Gantry Cranes			
Over one ton capacity	D/O, M/I	A/I	A/I
One ton and under capacity	D/O, M/I	A/I	P/I
Slings & Chanins	D/O, M/I		P/I
Hooks	D/O, M/I	A/I	
Wire Rope	M/I		
Sheaves		A/I	
Crawler, Locomotive & Truck Cranes	D/O, M/I	A/I	A/I
Slings & Chains	D/O, M/I		P/I
Hooks	D/O, M/I	A/I	
Wire Rope	M/I		
Sheaves		A/I	
Derricks	D/O, M/I	A/I	A/I
Slings & Chains	D/O, M/I		P/I
Hooks	D/O, M/I	A/I	
Wire Rope	M/I		
Sheaves		A/I	
Powered Industrial Trucks	D/O	S/I	
Elevators		S/I	

KEY

Inspections By:

O - Operator
I - Inspector

Frequency:
P - Prior to initial use
D - Daily
M - Monthly
Q - Quarterly
S - Semiannually
A - Annually

Daily inspections shall be performed each day or before each use of the equipment, whichever is less frequent.

APPENDIX G

USAEC MANUAL, CHAPTER 0550 AND SUPPLEMENT
OPERATIONAL SAFETY STANDARDS

AND

USAEC-ORO MANUAL, CHAPTER 0550
OPERATIONAL SAFETY STANDARDS

U.S. ATOMIC ENERGY COMMISSION
AEC MANUAL

Volume: 0000 General Administration
Part : 0500 Health and Safety

AEC 0550-01
OS

CHAPTER 0550 OPERATIONAL SAFETY STANDARDS

0550-01 POLICY

The AEC adopts or develops standards for the protection of AEC and AEC contractor employees, the general public, and the environment, and for minimizing damage to, or the loss of, property from the hazards resulting from AEC operations.

0550-02 OBJECTIVE

To assure that all aspects of AEC and AEC contractor operations are conducted in accordance with specifically identified operational safety standards to which exceptions or modifications are approved only when consistent with the intent of such standards.

0550-03 RESPONSIBILITIES AND AUTHORITIES

031 **The Director of Regulation** assures that the appropriate standards in appendix 0550 are implemented for areas under his jurisdiction. The Division of Operational Safety will provide guidance and assistance in fulfilling this responsibility.

032 **The Director, Division of Operational Safety:**

a. reviews nationally recognized health and safety requirements, guides, codes, and standards and prescribes those applicable to AEC activities.
b. determines the need for and develops, or promotes the development of, new or revised standards applicable to health and safety for AEC activities.
c. renders interpretations of applicable standards set forth in appendix 0550.
d. grants exceptions to the use of prescribed standards, when justified.
e. acts as liaison with the Occupational Safety and Health Administration of the Department of Labor and other organizations as appropriate.
f. recommends to the managers of field offices, and the Director, Division of Headquarters Services, the extent to which existing facilities should be modified to comply with changes in standards.

033 **The Directors, Divisions of Production and Materials Management, Naval Reactors, and Space Nuclear Systems,** assure compliance with the requirements of this chapter by field offices under their jurisdiction.

034 **The Director, Office of Information Services,** assures that a level of performance of health and safety is maintained, consistent with the intent of the prescribed standards set forth in appendix 0550, for Nuclear Science Demonstration Centers operated under his jurisdiction.

035 **Managers of Field Offices and the Director, Division of Headquarters Services, for Headquarters:**

a. apply the prescribed standards contained in appendix 0550 as minimum standards.
b. assure that the levels of performance of health and safety are maintained, consistent with the intent of these standards, for those activities under their direction.
c. may prescribe additional or more stringent standards, based upon determination that such standards are essential to safety and proper performance of their functions.
d. assure the maintenance of an up-to-date library and/or file of applicable standards, codes, and guides.
e. grant exceptions in accordance with subsection 057, below, from the requirements of this chapter and appendix where such actions will best serve the interests of the AEC, providing that the safety of employees, the public, and Government and private property can safely be maintained.

0550-04 DEFINITIONS

041 **Standards** include existing Federal, state, and local requirements and those recommended by various Government agencies, industrial organizations, technical associations, and other groups.

042 **AEC Contractor** includes any AEC prime contractor or subcontractor exempt from (or not subject to) AEC licensing, except Part 115 Reactors, but subject to the contractual provisions of AECPR 9-7.5006-47 or modifications thereof.

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043 Prescribed standards are those minimum requirements developed or adopted by AEC with which the AEC and its contractors must comply.

044 Recommended standards are those which AEC and its contractors shall consider utilizing in addition to the prescribed standards. Requirements issued to field offices and contractors by Headquarters program divisions are controlling when they are in conflict with recommended standards. (For reactors, field office managers shall determine which recommended standards apply to their operations and issue clear directions to contractors after assuring that these directions do not conflict with Headquarters program division requirements. Standards developed by the Division of Reactor Development and Technology (RDT) shall be considered for all AEC-owned reactors and appropriately applied except (1) when a field office determines for the record that a particular RDT standard does not apply or (2) when the responsible Headquarters program division director directs the field office to apply other standards considered appropriate for a particular facility. RDT concurrence is required for all exceptions involving reactors for which RDT has safety review responsibilities under annex A to AECM 0540.)

0550-05 BASIC REQUIREMENTS

051 **Applicability.** Provisions of this chapter and its appendix are applicable to and shall be followed:

a. by divisions and offices, Headquarters, field offices, and AEC contractors (pursuant to appropriate contract provisions), and military and civilian personnel of other Government agencies assigned to the AEC.
b. when changes, alterations, and modifications are made to existing facilities. It is not intended that existing physical facilities be changed arbitrarily to comply with the standards specified, except as required by law. (This assumes, of course, that the end objective can be reached with administrative controls supplementing the deficient system or facility.)

052 **Coverage.** This chapter and appendix cover the minimum prescribed standards to be used by AEC and AEC contractors. Where an AEC contractor is also an AEC licensee, the contract relationship will not exempt him from compliance with AEC regulations and the terms of his license; or where AEC contractors are tenants on a military installation and a Host-Tenant Agreement has been executed, the standards established by the host may be observed, unless AEC-prescribed standards provide for greater protection, in which case AEC standards shall be observed. Facilities covered by this chapter include those owned or leased by the AEC or leased by AEC contractors for use in AEC work, and include those of either a permanent or temporary (e.g., trailers) nature.

053 **Appendix 0550.** The latest editions of the prescribed standards listed in appendix 0550 are minimum requirements. The appendix sets forth standards, both prescribed and recommended, covering emergency preparedness, environmental protection, fire protection, health protection, industrial safety, nuclear safety, and transportation safety. In many instances standards are listed in the manual chapters referenced in their particular section. Should the user not note a particular standard in this appendix he should review the referenced manual chapter. The sources of supply for the standards and a glossary of abbreviations are contained in the appendix, exhibit 1.

054 **Conflicts in Standards.** If there are conflicts between prescribed standards in appendix 0550, the standards providing the greater protection shall govern.

055 **Reference.** Chapter 4123, "Attendance at Meetings and Participation in Outside Professional and Technical Organizations," covers participation in nuclear standards-making bodies.

056 **Federal Laws.** Working conditions of AEC contractor employees at contractor-operated, government-owned or -leased facilities are not subject to the Occupational Safety and Health Act of 1970.

The following standards, in addition to those listed in appendix 0550, shall be used as minimum prescribed standards at such facilities as applicable:

a. 29 CFR Part 1910 Occupational Safety and Health Standards
b. 29 CFR Part 1926 Safety and Health Regulations for Construction
c. 29 CFR Part 1915 Safety and Health Regulations for Ship Repairing
d. 29 CFR Part 1916 Safety and Health Regulations for Shipbuilding
e. 29 CFR Part 1917 Safety and Health Regulations for Shipbreaking
f. 29 CFR Part 1918 Safety and Health Regulations for Longshoring
g. Department of Defense Explosive Safety Board Standards (Ordnance Operations)
h. Department of Navy Standards (In-hull of naval prototypes)

057 Procedures for Granting Exceptions

a. Exceptions from the requirements of AEC Manual chapters referenced in this chapter shall be processed in accordance with the instructions contained in chapter 0201-054.

b. Managers of field offices and the Director, Division of Headquarters Services, are permitted to grant exceptions from the standards of this Manual chapter for a period of 6 months. They are required to notify the Director, Division of Operational Safety, of all exceptions granted, and if such exceptions are for periods greater than 6 months, they must be approved by the Director, Division of Operational Safety.

c. Exceptions are considered to be of a temporary nature until corrective action can be taken. When requesting exceptions, managers of field offices and the Director, Division of Headquarters Services, should also include with their requests plans to ameliorate the conditions requiring the exceptions.

0550-06 NATIONAL EMERGENCY APPLICATION

During a national emergency, as defined in chapter 0601-06, the provisions of this chapter and appendix shall continue in effect.

PART I

EMERGENCY PREPAREDNESS

A. PRESCRIBED STANDARDS

1. Telecommunications, Chapter 0270 and Appendix 0270, part VIII.
2. Radiological Assistance Program, AECM 0526.
3. AEC Response to Accidents Involving Nuclear Weapons in the Custody of the DOD, AECM 0527.
4. Planning for Emergencies in AEC Operations, AECM 0544.
5. Prevention of Accidental or Unauthorized Nuclear Detonations, AECM 0560.
6. National Emergency, Defense, and Mobilization (EDM) Preparedness Program, AECM 0601.
7. Immediate Evacuation Signal for Use in Industrial Installations Where Radiation Exposure May Occur, N 2.3-1967 (ANSI).

B. RECOMMENDED STANDARDS

1. Exposure to Radiation in an Emergency, NCRP Report No. 19.
2. Basic Radiation Protection Criteria, NCRP Report No. 39.
3. E.O. 11490, Assigning Emergency Preparedness Functions to Federal Departments and Agencies.
4. National Plan for Emergency Preparedness.
5. Office of Emergency Preparedness Circulars.
6. Federal Civil Defense Guide.
7. Planning for the Handling of Radiation Accidents, Safety Series 32 (IAEA).
8. Plans for Coping with Emergencies, 10 CFR 50, Appendix E and Associated Guide.

PART II

ENVIRONMENTAL PROTECTION

A. PRESCRIBED STANDARDS

1. Prevention, Control, and Abatement of Air and Water Pollution, AECM 0510.
2. Air and Water Pollution Control Standards Promulgated Pursuant to the Clean Air Act (42 U.S.C. 1857 et seq.) and the Federal Water Pollution Control Act (33 U.S.C. 466 et seq.).
3. Intrastate or Interstate Regulations of Air and Water Pollution Control Authorities.
4. Effluent and Environmental Monitoring and Reporting, AECM 0513.

B. RECOMMENDED STANDARDS

1. Standard Methods for the Examination of Water, Sewage, and Industrial Wastes (AWWA).
2. Guide for Use of Insecticides, Handbook 290 (USDA).
3. Manual of Septic-Tank Practice, Pub. No. 526 (USPHS).
4. Sanitary Landfill Facts, Pub. No. 1792 (USPHS).
5. Interim Guide of Good Practice for Incineration at Federal Facilities, Pub. No. AP-46 (USPHS).
6. Incinerator Guidelines, Pub. No. 2012 (USPHS).
7. Air Pollution Engineering Manual, Pub. No. AP-40 (USPHS).

PART III

FIRE PROTECTION

A. PRESCRIBED STANDARDS

1. Industrial Fire Protection, AECM 0552.
2. General Design Criteria, AECM 6301.
3. National Fire Codes (NFPA).
4. Standard For Fire Protection of AEC Electronic Computer Data Processing Systems. (Compliance with this standard satisfies the requirements for NFPA-75.) (AEC).
5. Lists of Inspected Appliances, Equipment, and Materials (UL).
6. Factory Mutual Approval Guide.
7. TP20-11 General Fire Fighting Guidance for Nuclear Weapons--CDC (AEC/NDA).

B. RECOMMENDED STANDARDS

1. Handbook of Fire Protection (NFPA).
2. Fire Prevention Code (AIA).
3. Loss Prevention Data Sheets (FM). (Replaces Handbook of Ind. Loss Prev.)
4. Fire Protection Guide on Hazardous Materials (NFPA).

PART IV

HEALTH PROTECTION

A. RADIATION PROTECTION

1. Prescribed Standards:
   a. Standards for Radiation Protection, AECM 0524.
   b. Occupational Radiation Exposure Information, AECM 0525.
   c. Nuclear Accident Dosimetry Program, AECM 0545.
   d. Performance Specifications for Direct Reading and Indirect Reading Pocket Dosimeters for X and Gamma Radiation N13.5-1972 (ANSI).
   e. Radiation Symbol, N2.1-1969 (ANSI).
   f. Radiological Safety in the Design and Operation of Particle Accelerators N43.1-1969 (ANSI).

2. Recommended Standards:
   a. Applicable (FRC) Reports (#1-1960, #2-1962, #5-1964, #7-1965, #8 (Revised).
   b. Handbooks, NCRP Recommendations (NBS).
   c. Guide to Sampling Airborne Radioactive Materials in Nuclear Facility N13.1-1969 (ANSI).
   d. Specification and Performance of On-site Instrumentation for Continuously Monitoring Radioactivity in Effluents, N13 Series (ANSI) in Draft Status.
   e. Film Badge Performance Criteria, N13.8-1972 (ANSI).
   f. Other ANSI Standards as applicable.
   g. Standards for Protection Against Radiation, 10 CFR 20.
   h. Radiation Protection Standards Reports (ICRP).
   i. An Annotated Bibliography of Regulations, Standards, and Guides for Microwaves, Ultraviolet Radiation, and Radiation From Lasers and Television Receivers (USPHS).
   j. Reports (ICRU).
      (1) Report 20, 1971, Radiation Protection Instrumentation and its Application.
      (2) Report 11, 1968, Radiation Quantities and Units.
      (3) Report 14, 1969, Radiation Dosimetry.
   k. Safety Series (IAEA).
   l. Electronic Product Radiation Control, Subpart 3 of PL 90-602, as amended on 10-18-68.

B. OCCUPATIONAL MEDICINE

1. Prescribed Standards:
   a. Occupational Health Program, AECM 0528.
   b. Employee Occupational Health Services Program, AECM 4161.

2. Recommended Standards:
   a. Scope, Objectives, and Functions of Occupational Health Programs, American Medical Association Council on Occupational Health (revised Dec. 1971).
   b. Occupational Health Services for Employees, U.S. Department of Health, Education, and Welfare. Public Health Service publication no. 1041 (May 1963).
   c. An Administrative Guide for Federal Occupational Health Units. HEW, Public Health Service publication no. 1325-A (Mar. 1966).
   d. Epidemiology in Occupational Disease and Injury, American Medical Association Council on Occupational Health (Sept. 1967).
   e. Medical Aspects of Radiation Accidents Handbook, Eugene L. Saenger, M.D., Editor (GPO).

C. INDUSTRIAL HYGIENE

1. Prescribed Standards:
   a. Current Threshold Limit Values (ACGIH).
   b. Air Force Manual 160-3, Medical Service-Hazardous Noise Exposure (Surgeon-Gen. USAF).
   c. Safety Standards for Lasers, ANSI Z.136 (ANSI) (in preparation).
   d. Practices for Respiratory Protection, Z88.2-1969 (ANSI).

2. Recommended Standards:
   a. Hygienic Guide Series (AIHA).
   b. Standards on Concentrations of Toxic

Dusts and Gases, Z.37 (ANSI).

c. Approved Respiratory Protection Devices Listing, Bureau of Mines (DOI).
d. Heating and Cooling for Man in Industry (AIHA).
e. Respiratory Protective Devices Manual (AIHA and ACGIH).
f. Industrial Ventilation Manual (ACGIH).
g. Rating Noise with Respect to Hearing Conservation, Speech Communication, and Annoyance (ISO).
h. Industrial Noise Manual (AIHA).
i. Guide for Conservation of Hearing and Noise (AAOO).
j. Fundamentals of Industrial Hygiene (NSC).

D. PUBLIC HEALTH AND SANITATION

1. Prescribed Standards:
   a. Water
      (1) Drinking Water Standards, Bulletin 956 (EPA).
      (2) Manual of Recommended Water-Sanitation Practice, Bulletin 525 (EPA).
      (3) Manual of Water Quality and Treatment (AWWA).
      (4) Sanitation Manual for Public Ground Water Supplies, Reports 59:137-177, Reprint 2539 (EPA).
      (5) Standards and Specifications for Water Supply, Treatment, Distribution System, and Storage Equipment, Materials and Procedures (AWWA).
      (6) Sanitary Standard for Manufactured Ice, Bulletin 1183 (USPHS).
      (7) Water Supply and Plumbing Cross-Connections, Pub. No. 957 (EPA).
      (8) Manual of Individual Water Supply Systems, Pub. No. 24 (EPA).
      (9) Regulations Covering Public Swimming Pools (Joint Committee APHA-PHS).
   b. General
      (1) State and Local Public Health Codes, which cover sanitation for eating and drinking establishments, practice of barbering, vending of food and beverages, and sanitation of buses. Where codes are incomplete, use publications 546; 934; 90; and 1534 (USPHS).
      (2) Sanitation in Places of Employment, ANSI Z4.1 (ANSI).
      (3) Lead Base Paint Poisoning Prevention Act Title 21, Food and Drugs, Chapter I, (Subchapter D, Part 191) (PL 91-695).

PART V

INDUSTRIAL SAFETY

A. GENERAL SAFETY

1. Prescribed Standards:
   a. General Design Criteria, AECM 6301.
   b. American National Standards Institute (ANSI) Standards for Safety as applicable.
   c. Forest Service Safety Standards (USDA).
   d. Boiler and Pressure Vessel Code, Sections I-XI (ASME).

2. Recommended Standards:
   a. Chemical Rocket Propellant Hazards JANNAF Propulsion Committee,
      Volume I—General Safety Engineering Design Criteria. N.T.I.S.-AD 889763. May 1970.
      Volume II—Solid Rocket Propellant Processing, Handling, Storage and Transportation. N.T.I.S.-AD 870258. May 1970.
      Volume III—Liquid Propellant Handling, Storage and Transportation. N.T.I.S.-AD 870259. May 1970. (Quantity distance tables are excepted-OSHA/NFPA QD tables apply where appropriate).
   b. Manual Sheets (MCA).
   c. Chemical Safety Data Sheets (MCA).
   d. Accident Prevention Manual for Industrial Operations. (NSC).
   e. Supervisor's Safety Manual (NSC).
   f. Handbook of Laboratory Safety (The Chemical Rubber Company).
   g. Handbook of Rigging, W.E. Rossnagel. McGraw-Hill Book Co., Inc., publishers.
   h. Data Sheet Series (NSC).
   i. Matheson Gas Data Book (The Matheson Company, Inc.).
   j. Handling Hazardous Materials, NASA SP-5032 (NASA).
   k. Testing Materials Standards (ASTM) (those applicable to safety).
   l. Handbook of Compressed Gases (CGA).
   m. Service Station Safety, Accident Prevention Manual 5 (API).

B. CONSTRUCTION SAFETY

1. Prescribed Standards:
   a. Construction Safety Program, AECM 0505.
   b. Pipeline Safety Standards Title 49 CFR Part 192.

2. Recommended Standard:
   Manual of Accident Prevention in Construction (AGCA).

C. CRANE SAFETY

1. Prescribed Standards:
   a. ANSI Series B 30.2 through B 30.9 (ANSI).
   b. Crane Manufacturers Association of America, Specification No. 70 (CMAA).

2. Recommended Standards:
   a. Requirements for Hoisting and Rigging of Special Components and Equipment RDT F8-6.
   b. Installation and Use of Life Safety Protection Equipment for Tower, Hammerhead and Other Horizontal Boom Cranes. (See annex C.)

D. DRILLING SAFETY

1. Prescribed Standards:
   a. Petroleum Safety Orders, Administrative Code, Title 8, chapter 4, subchapter 14. State of California (except the requirement of paragraph (b) Section 6640, of article 41 of the 1959 orders is permanently waived—API RP 9B applies).
   b. Applicable Division of Production Specifications and Recommended Practices on Oil Field Equipment (API).
   c. Safe Practices in Drilling Operations, Third Edition, 1967 RP 2010 (API).

2. Recommended Standards:
   a. Rotary Drilling Handbook on Accident Prevention and Safe Operating Practices (IAODC).
   b. Applicable Division of Production Bulletins (API).

E. ELECTRICAL SAFETY

1. Prescribed Standards:
   a. National Electrical Code, NFPA 70 (ANSI-CI).
   b. National Electrical Safety Code (ANSI-C2).

2. Recommended Standards:
   a. Electrical Engineering Regulations CG-259, U.S. Coast Guard (DOT).
   b. Miscellaneous Electrical Equipment List, CG-293, U.S. Coast Guard (DOT).
   c. Safety Rules for the Installation and Maintenance of Electric Supply and Communication Lines, NBS No. 81.
   d. Electrical Safety Guides for Research, Safety and Fire Protection Bulletin No. 13 (AEC).
   e. Safety Guidelines for High Energy Accelerator Facilities, TID 23992 (AEC).
   f. IEEE Standards for Safety (Institute of Electrical and Electronics Engineers).

F. EXPLOSIVES SAFETY

1. Prescribed Standards:
   a. Safety Manual, AMCR 385-100, Headquarters, U.S. Army Materiel Command (AMC).
   b. DOD Ammunition and Explosives Safety Standards, DOD 4145.27M (DOD).
   c. Blaster's Handbook (DUPONT).

2. Recommended Standards:
   a. Rules for Storing, Transporting, and Shipping Explosives, Pamphlet 5 (IME).
   b. Safety in the Transportation, Storage, Handling, and Use of Explosives, Pamphlet 17 (IME).
   c. Structures to Resist the Effects of Accidental Explosions. Dept. of the Army Tech, Manual TM5-1300.
   d. Safety Guide for the Prevention of Radiofrequency Radiation Hazards, Pamphlet 20 (IME).
   e. Evaluation of Explosive Storage Safety Criteria, May 1970, AD 871 194 (NTIS).

G. FIREARM SAFETY

1. Prescribed Standards:
   a. Physical Protection Handbook (GSA).
   b. Pistols and Revolvers, FM 23-35, 7-60 (AMC).
   c. Safety with Firearms Handbook (NRA).
   d. Firearms Handling Handbook (NRA).
2. Recommended Standards:
   a. Education and Training Security Police, Training Course AMCP 621-1 (621-1 AMC).
   b. Military Police Preservation of Order Activities, AMCR 190-3, 12-71 (AMC).

H. MINE AND TUNNEL SAFETY

1. Prescribed Standards:
   a. Federal Metal and Nonmetallic Mine Safety Act. Public Law 89-5771, Standards, 30 CFR 55, 56, 57.
   b. Tunnel Safety Orders, Administrative Code, title 8, chapter 4, subchapter 20, State of California.
   c. Mine Safety Orders, Administrative Code, title 8, chapter 4, subchapter 12, State of California.

2. Recommended Standards:
   Tunneling: Recommended Safety Rules, Bulletin 644, Bureau of Mines.

PART VI

NUCLEAR SAFETY

A. REACTOR SAFETY

1. Prescribed Standard:
   Safety of AEC-Owned Reactors, AECM 0540.

2. Recommended Standards:
   a. Applicable RDT Standards. (See index of RDT Standards.)
   b. Licensing of Production and Utilization Facilities, 10 CFR 50 and appendix, including safety guides issued to describe methods of implementing these regulations.
   c. Operators' Licenses, 10 CFR 55.
   d. Reactor Site Criteria, 10 CFR 100.
   e. Procedures for Review of Certain Nuclear Reactors Exempted from Licensing Requirements, 10 CFR 115.
   f. Safe Operation of Critical Assemblies and Research Reactors, 1971 Edition, Safety Series No. 35 (IAEA).
   g. Safe Operation of Nuclear Power Plants, Safety Series 31 (IAEA).
   h. ANSI Standards as applicable.

B. NUCLEAR CRITICALITY SAFETY

1. Prescribed Standard:
   a. Nuclear Criticality Safety, AECM 0530.
   b. Prevention of Accidental or Unauthorized Nuclear Detonations, AECM 0560.

2. Recommended Standards:
   a. Nuclear Safety Guide, TID-7016 (AEC).
   b. Criticality Accident Alarm System, N16.2 (ANSI).
   c. Safety Standards for Operations with Fissionable Materials Outside Reactors, N16.1 (ANSI).
   d. Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Materials, N16.4 (ANSI).
   e. Critical Dimensions of Systems Containing Uranium-235, Plutonium-233, and Uranium-233, TID-7028 (AEC).
   f. Critical and Safe Masses and Dimensions of Lattices of U and UO_2 In Water, DuPont-1014.
   g. United Kingdom Atomic Energy Authority Handbook of Criticality Data, AHSB(S), Handbook 1 (1st Revision).
   h. Criticality Handbook, ARH-600 (3 volumes).

C. MATERIALS FACILITY SAFETY

1. Prescribed Standards:
   a. Safety of AEC-owned Radioactive Materials Processing Facilities. (Manual chapter is being prepared.)
   b. Storage Criteria for Unirradiated Enriched Uranium.* (AEC Gen. Mgr. letter dated May 10, 1972.)
   c. Criteria for Plutonium Storage Facilities.* (AEC Dep. Gen. Mgr. letter dated March 18, 1971.)
   d. Minimum Design Criteria for New Plutonium Processing Facilities.*
   (CONS draft criteria dated June 14, 1972)

   *Design portion will be incorporated in AECM 6301.

2. Recommended Standards:
   a. Licensing of Production and Utilization Facilities, 10 CFR 50.
   b. Special Nuclear Material, 10 CFR 70.
   c. Rules of General Applicability to Licensing of By-product Material, 10 CFR 30.
   d. Licensing of Source Material, 10 CFR 40.
   e. Operators' Licenses, 10 CFR 55.
   f. Appropriate Portions of Reactor Site Criteria, 10 CFR 100.
   g. Design, Construction, and Testing of High Efficiency Air Filtration Systems for Nuclear Application, ORNL-NSIC-65 (ANSI).
   h. ANSI standards as applicable.
   i. RDT standards as applicable.

Approved: March 26, 1973

PART VII

TRANSPORTATION SAFETY

A. AIRCRAFT SAFETY

Prescribed Standard:
Federal Aviation Regulations (DOT).

B. MOTOR VEHICLE AND TRAFFIC SAFETY

1. Prescribed Standards:
   a. Motor Vehicle Operator Standards, AECM 0553.
   b. Standards for Installation and Use of Seat Belts. (See appendix 0550, annex A.)
   c. Standards for Placarding Vehicles that Stop at Railroad Crossings. (See appendix 0550, annex B.)
   d. Motor Carrier Safety Regulations, Federal Highway Administration (DOT).
   e. Hazardous Materials Regulations, R.M. Graziano's Tariff No. 25 (DOT).
   f. Manual on Uniform Traffic Control Devices for Streets and Highways, Bureau of Public Roads (DOT).
   g. Inspection Requirements for Motor Vehicles, Trailers and Semi-trailers, Operated on Public Highways, ANSI D7.1 (ANSI).
   h. Uniform Vehicle Code (NCUTLO).
   i. A Policy on Geometric Design on Rural Highways (AASHO).

2. Recommended Standards:
   a. Traffic Engineer's Handbook (ITE and NSC).
   b. Traffic Engineering. Matson, Smith and Hurd. McGraw-Hill Book Company, Inc., publishers.
   c. Motor Fleet Safety Manual (NSC).
   d. Traffic Accident Investigator's Manual for Police, The Traffic Institute, Northwestern University.
   e. Handbook of Highway Safety Design and Operating Practices. (DOT).

C. VESSELS (MARINE) SAFETY

1. Prescribed Standards:
   a. Rules and Regulations for Uninspected Vessels, Booklet 258, U.S. Coast Guard (DOT).
   b. Rules and Regulations for Numbering of Undocumented Vessels and the Reporting of Boating Accidents, Booklet 267, U.S. Coast Guard (DOT).
   c. Equipment Lists, Booklet 190, U.S. Coast Guard (DOT).
   d. Marine Engineering Regulations and Material Specifications, Booklet 115, U.S. Coast Guard (DOT).
   e. Ventilation System for Small Craft, Booklet 395, U.S. Coast Guard (DOT).

D. TRANSPORTATION OF RADIOACTIVE MATERIAL

1. Prescribed Standards:
   a. Safety Standards for the Packaging of Radioactive and Fissile Materials, AECM 0529.
   b. Transportation and Traffic Management, AECM 5201.
   c. Nuclear Criticality Safety, AECM 0530 (applies for fissionable materials).
   d. CFR Title 49—Department of Transportation Hazardous Materials Regulations, Parts 170-189.
   e. Packaging of Radioactive Material for Transport, 10 CFR 71.
   f. Physical Protection of Special Nuclear Material, 10 CFR 73.

2. Recommended Standards:
   a. Guide to Practice in Transportation of Source and Special Nuclear Material Before Irradiation, ANSI N5.1 (ANSI).
   b. Guide for Design and Operation of Shipping Containers for Irradiated Solid Fuel from Nuclear Reactors, ANSI N5.3 (ANSI).
   c. Cask Designers Guide ORNL—NSIC-68, 1970 (AEC).
   d. Structural Analysis of Shipping Casks, ORNL-TM-1312, Volumes I thru X (AEC).
   e. Packaging of Uranium Hexafluoride for Transport, ANSI N14.1-1971 (ANSI).

E. RAILROAD SAFETY

1. Prescribed Standard:
   Federal Railroad Administration, 49 CFR 211-240 (DOT).

F. RADIOACTIVE WASTE MANAGEMENT

1. Prescribed Standards:
   a. Radioactive Waste Management, AECM 0511. (Manual chapter in preparation.)
   b. Plan for the Management of AEC–Generated Radioactive Wastes, WASH-1202 (GPO).

ANNEX A

STANDARDS FOR INSTALLATION AND USE OF SEAT BELTS

1. Installation

To the extent specified herein, every vehicle under the control of the AEC shall be equipped with seat belts for each driver and passenger position in accordance with applicable Federal standards and specifications published by the General Services Administration, Federal Supply Services, Automotive Standards Division (GSA-FSS).

a. All vehicles designed and constructed for the use of Type 2 or 2a (Fed. Std. 515/la, S3.2.5 & 3.2.6) seat belt (lap belt-upper torso belt combination) assemblies shall be so equipped. (All 1968 and later models are required to have, and some earlier models may have, built-in anchorages for Type 2 or 2a seat belt assemblies for each outboard passenger position).

b. Vehicle models of earlier dates, designed and constructed for the use of lap belts only, shall be equipped with Type 1 (Fed. Std. 515/la, S3.2.4) seat belts. Earlier vehicle models constructed with sufficient strength in the door posts and roof rails and equipped with anchorages to meet requirements for use of Type 2 or 2a seat belts shall be so equipped. Manufacturer's instructions shall be followed for such installations.

c. Buses, 1968 and later models, other than schoolbus types, shall be equipped with seat belts for all passengers and drivers. Bus models earlier than 1968 shall be equipped with seat belts for drivers. Until later notice, Type 1 seat belts shall be provided for bus drivers and for bus passengers when buses are equipped with built-in seat belt anchorages. (Older model buses are not designed or constructed with the necessary strength in passenger seat assemblies, seat anchorages or for appropriate seat belt anchorages).

2. Use

a. Each AEC and AEC contractor employee operating or riding in an AEC vehicle shall wear his seat belt, when provided, at all times while the vehicle is in motion.

b. The driver of any AEC vehicle (except buses) shall not place the vehicle in motion until he has assured himself that all passengers have fastened their seat belts, where so equipped, and that his own seat belt is fastened.

Approved: November 8, 1968
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ANNEX B

STANDARDS FOR PLACARDING VEHICLES THAT STOP AT RAILROAD CROSSINGS

1. **AEC and AEC contractor vehicles shall:**

   a. be equipped with a sign on the rear in retroflective letters, at least 3 inches high, on a background of contrasting color, clearly indicating that the motor vehicle stops at railroad crossings.

   b. be fitted with appropriate means for using removable signs while in temporary custody when such signs are not provided with the vehicle or cannot be permanently painted on the vehicle.

2. **The above standards are applicable to:**

   a. buses transporting passengers.

   b. motor vehicles transporting any quantity of explosives, Class A or B as defined by the DOT's regulations.

   c. motor vehicles transporting any quantity of poison gas, Class A.

   d. motor vehicles transporting any quantity of chlorine.

   e. motor vehicles which, in accordance with the DOT's regulations, are required to be marked or placarded with one of the following markings: (1) Dangerous; (2) Compressed Gases; (3) Dangerous—Radioactive Materials; or (4) Chlorine.

   f. cargo tank motor vehicles, whether loaded or empty, used for the transportation of any dangerous article, as defined in the regulations of the DOT, or for the transportation of any liquid having a flashpoint below 200°F., as determined by the Standard Method of Test for Flashpoint of the American Society for Testing and Materials (ASTM), as set forth in ASTM D-56-61, ASTM D-92-57, or ASTM D-93-62, and referenced by the National Fire Protection Association (NFPA), in pamphlet No. 385, 1964 edition.

   g. cargo tank motor vehicles transporting a commodity which, at the time of loading, has a temperature above its flashpoint as determined by the same standard method of testing as prescribed in section 192.10(a)(6).

   h. cargo tank motor vehicles, whether loaded or empty, transporting any commodity under special permit in accordance with the provision of section 73.22, Title 49, Code of Federal Regulations.

Approved: November 8, 1968
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ANNEX C

STANDARDS FOR THE INSTALLATION AND USE OF LIFE SAFETY PROTECTION EQUIPMENT FOR TOWER, HAMMERHEAD, AND OTHER HORIZONTAL BOOM CRANES

AEC and AEC contractors using tower, hammerhead, or other horizontal boom cranes shall provide protection against falling for workmen required to perform duties on the horizontal boom of any such crane. Protection provided shall afford safe access to all parts of the boom requiring inspection, lubrication, or other regular service.

The following shall be considered minimum requirements, but shall not preclude the use of other approved safeguarding methods providing equal or better protection, such as complete catwalks, safety nets, etc.

a. A stranded wire safety cable shall be installed securely above the entire length of the boom, with intermediate supports as necessary.
b. Cables, fastenings, and supports shall be of a size sufficient to support the weight of the maximum number of men necessary to perform any required work at one time, with a factor of safety of five (5).
c. Cable and fastenings shall be tested with a dummy load equal to twice the manload for which the cable will be used. Tests shall be performed prior to initial use by workmen each time the crane is erected, and at such intervals as specified by the local authority having jurisdiction, but not less than quarterly during regular operation.
d. Workmen required to perform work on the boom shall wear approved safety belts and shock absorber safety lanyards with self-closing hooks and shall be required to be hooked onto the safety cable at all times when walking, climbing, or working on the horizontal boom of such cranes.

NOTE: Method of attachment and location of strain-bearing parts shall be such that they will not weaken or damage the structural members of the boom or interfere with operations.

Approved: February 25, 1970
Reprinted: March 26, 1973

EXHIBIT 1

SOURCES OF SUPPLY FOR STANDARDS

(AAODC) American Association of Oilwell Drilling Contractors
211 North Ervay Building, Room 505
Dallas, Texas 75201

(AAOO) American Academy of Ophthalmology & Otolaryngology
15 Second Street, S.W.
Rochester, Minnesota 55901

(AASHO) American Association of State Highway Officials
341 National Press Building
Washington, D.C. 20004

(ACGIH) American Conference of Governmental Industrial Hygienists
1014 Broadway
Cincinnati, Ohio 45202

(ANSI) American National Standards Institute
1403 Broadway
New York, New York 10018

(AEC) United States Atomic Energy Commission
Washington, D.C. 20545

(AGCA) Associated General Contractors of America, Inc.
1957 E Street, N.W.
Washington, D.C. 20006

(AIA) American Insurance Association
85 John Street
New York, New York 10038
(formerly American Association of Casualty and Surety Co.)

(AIHA) American Industrial Hygiene Association
14125 Prevost
Detroit, Michigan 48227

(AISC) American Institute of Steel Construction, Inc.
101 Park Avenue
New York, New York 10017

(AMC) Army Materiel Command
United States Department of the Army
The Pentagon
Washington, D.C. 20310

(API) American Petroleum Institute
Division of Production
300 Corrigan Tower Building
Dallas, Texas 75201

(ASME) American Society of Mechanical Engineers
345 East 49th Street
New York, New York 10016

(ASTM)	American Society for Testing Materials 1916 Race Street Philadelphia, Pennsylvania 19103
(ATT)	American Telephone and Telegraph Company 195 Broadway New York, New York 10007
(AWWA)	American Water Works Association 2 Park Avenue New York, New York 12603
(OMB)	Office of Management and Budget Executive Office Building Washington, D.C. 20503
(CGA)	Compressed Gas Association 500 5th Avenue New York, New York 10036
(CMAA)	Crane Manufacturers Association of America 1326 Free Port Road Pittsburgh, Pennsylvania 15238
(DOD)	United States Department of Defense The Pentagon Washington, D.C. 20310
(DOI)	United States Department of the Interior Washington, D.C. 20240
(DOL)	United States Department of Labor Washington, D.C. 20210
(DOT)	United States Department of Transportation Washington, D.C. 20590
(DOT)	United States Coast Guard Department of Transportation 1300 E Street, N.W. Washington, D.C. 20004
(DUPONT)	E.I. duPont de Nemours and Company Explosive Department Wilmington, Delaware 19898
(EPA)	Environmental Protection Agency 401 M Street S.W. Washington, D.C. 20024
(FCPC)	Federal Committee on Pest Control United States Dept. of Health, Education, and Welfare 8120 Woodmont Avenue Washington, D.C. 20014

(FFC)	Federal Fire Council General Services Administration Washington, D.C. 20405
(FIA)	Factory Insurance Association 85 Woodland Street Hartford, Connecticut 06105
(FM)	Factory Mutual Engineering Division 1151 Boston-Providence Turnpike Norwood, Massachusetts 02062
(FRC)	Federal Radiation Council Washington, D.C. 20449
(FSC)	Federal Safety Council Washington, D.C. 20210
(GPO)	Superintendent of Documents United States Government Printing Office Washington, D.C. 20402
(GSA)	General Services Administration Washington, D.C. 20405
(IAEA)	International Atomic Energy Agency 9-13 Kaertnerring Vienna, Austria
(ICBO)	International Conference of Building Officials 50 South Los Robles Street Pasadena, California 91101 (formerly Pacific Coast Building Officials Conference)
(ICRP)	International Committee on Radiation Protection 4201 Connecticut Avenue, N.W. Washington, D.C. 20008
(IES)	Illuminating Engineering Society 1860 Broadway New York, New York 10023
(IME)	Institute of Makers of Explosives 420 Lexington Avenue New York, New York 10017
(ISO)	International Standards Organization 23 rue Notre Dame des Victoires Paris, France
(ITE)	Institute of Traffic Engineers 1725 deSales Street, N.W. Washington, D.C. 20036
(MCA)	Manufacturing Chemists' Association, Inc. 1825 Connecticut Avenue, N.W. Washington, D.C. 20009

(NASA) National Aeronautics and Space Administration
Washington, D.C. 20546

(NBS) National Bureau of Standards
Department of Commerce
Washington, D.C. 20234

(NCRP) National Council on Radiation Protection
4201 Connecticut Avenue, N.W.
Washington, D.C. 20008

(NCUTLO) National Committee on Uniform Traffic Laws and Ordinances
525 School Street, S.W.
Washington, D.C. 20024

(NFPA) National Fire Protection Association
60 Batterymarch Street
Boston, Massachusetts 02110

(NRA) National Rifle Association
1600 Rhode Island Avenue, N.W.
Washington, D.C. 20036

(NSC) National Safety Council
425 North Michigan Avenue
Chicago, Illinois 60611

(NTIS) United States Department of Commerce
National Technical Information Service
Springfield, Virginia 22151

(UL) Underwriters' Laboratories, Inc.
207 East Ohio Street
Chicago, Illinois 60611

(USDA) United States Department of Agriculture
Washington, D.C. 20250

(USPHS) United States Public Health Service
Department of Health, Education, and Welfare
Washington, D.C. 20203

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UNITED STATES ATOMIC ENERGY COMMISSION
AEC MANUAL

OAK RIDGE IMMEDIATE ACTION DIRECTIVE

ORIAD NO. 0550-23 **DATE:** December 17, 1974

SUBJECT: OPERATIONAL SAFETY STANDARDS

1. In accordance with AECM 0550-035c. the following safety standard shall be used as a prescribed General Safety Standard within ORO:

   General Safety Requirements, EM 385-1-1
   (U. S. Corps of Engineers)

2. This standard is applicable to all Divisions, TIC, and contractors (pursuant to appropriate contract provisions) under their jurisdiction.

for R. J. Hart
Manager

U. S. ATOMIC ENERGY COMMISSION
AEC MANUAL

Oak Ridge Operations Office

Volume: 0000 General Administration OR-0550
Part: 500 Health and Safety

Chapter OR-0550 OPERATIONAL SAFETY STANDARDS

0550-03 Responsibilities and Authorities.

034 Managers of Field Offices:

a. Division Directors, Area Managers, and the Extension Manager, DTIE, in the administration of contract activities: (R)

1. Assure that the codes and standards detailed in AEC Appendix 0550 are applied as minimum standards by their contractors, and that the levels of performance of health and safety are maintained, consistent with the intent of these standards.

2. Make recommendations to the Manager for additional or more stringent standards deemed essential to the safety and proper performance of their functions, and for granting any ~~temporary~~ exceptions from the requirements of the AEC Chapter and its Appendix.

See TN-0500-58

b. Director, Safety Division: (N)

1. Performs appraisals of contractor operations for compliance with prescribed standards and for levels of performance in health and safety activities.

2. Maintains a library of safety standards, codes, and guides.

3. Prepares written reports to the Director, Division of Operational Safety, on any exceptions granted.

4. Provides clarification of the technical requirements of Chapters AEC and OR-0550.

Approved: February 19, 1969
TN-0500-47

0550-05 Basic Requirements.

(R) 051 Applicability.

The provisions of Chapters AEC and OR-0550 are applicable to all Divisions, Area Offices, and DTIE, and to contractors (pursuant to appropriate contract provisions) under their jurisdiction.

0550-06 National Emergency Application.

During a national emergency, as defined in Section AEC-0601-04, the provisions of this OR Chapter and Appendix shall continue in effect, unless superseded by direction of the Manager, ORO.

A. Building Codes.

1. The use of the "Southern Standard Building Code," published by the Southern Building Code Congress, Birmingham, Alabama, is required by Oak Ridge Operations for projects located east of the Mississippi River and south of the Ohio River and in the state of Pennsylvania as specified in AEC appendix 6301, "General Design Criteria." Projects located on the Island of Puerto Rico are designed to meet the minimum requirements of the "Building Regulation" as published by the Puerto Rico Planning Board, Santurce, Puerto Rico.

   For purposes of interpretation of the provisions of the "Southern Standard Building Code" as they apply to projects located in the Oak Ridge area, all such projects located on Government-owned or leased land shall be considered as being located outside of any designated fire districts.

2. The "Uniform Building Code," published by the International Conference of Building Officials, Los Angeles, California, is used elsewhere in Oak Ridge Operations.

B. Fire Standards. (R)

The publication "Fire Prevention and Protection Guides for ORO" is applicable to all contractual activities which are required to be conducted in compliance with the fire protection regulations and requirements (including reporting requirements) of the Commission. This pamphlet should be generally followed to provide the most effective program at the lowest possible cost.

C. Safety Standards. (N)

AEC standards require that employees shall use eye and face protection equipment when machines or operations present potential eye or face injuries. It shall be the policy for ORO facilities to:

1. Have all personnel wear approved type eye protection in any operational area designated as "eye hazard."

2. Have all construction workers wear approved type eye protection at their respective job sites.

3. Grant exemption to 1 and 2 above according to paragraph OR 0550-034 a.2.

Approved: October 31, 1974
TN 0500-91

APPENDIX H

AEC MANUAL, CHAPTER 0524
STANDARDS FOR RADIATION PROTECTION

Form AEC-489
(6-67)

U. S. ATOMIC ENERGY COMMISSION
AEC MANUAL

TRANSMITTAL NOTICE

Chapter 0524 STANDARDS FOR RADIATION PROTECTION

SUPERSEDED: Number	Date	**TRANSMITTED:** Number	Date
		TN 0500-63	
Chapter		Chapter	
Page		Page	
Appendix 0524 (except Annex A)	11/8/68	Appendix 0524 (except Annex A)	2/4/69

REMARKS:

This appendix (except Annex A) has been reprinted. Material in paragraphs II and III has been rearranged for clarity and conformity with paragraph I.

U.S. ATOMIC ENERGY COMMISSION
AEC MANUAL

Volume: 0000 General Administration
Part : 0500 Health and Safety

AEC 0524-01
OS

Chapter 0524 STANDARDS FOR RADIATION PROTECTION

0524-01 POLICY

011 Radiation protection standards applicable to AEC and AEC contractor operations not subject to AEC licensing, shall be established to protect the general public, AEC and AEC contractor personnel and property.

012 AEC and AEC contractor operations shall be conducted in such a manner as to assure that radiation exposures to individuals and population groups are limited to the lowest levels technically and economically practical.

0524-02 OBJECTIVE

To establish radiation protection standards for AEC and AEC contractor operations consistent with the Radiation Protection Guides recommended by the Federal Radiation Council and with the standards approved by the Commission for the regulation of licensee operations.

0524-03 RESPONSIBILITIES AND AUTHORITIES

031 The Director, Division of Operational Safety:

a. develops, or promotes the development of, radiation protection standards and policies relating to AEC and AEC contractor operations.

b. approves or disapproves each proposed exception to the radiation protection standards established by this chapter.

c. appraises the performance of AEC field offices and upon request, or when circumstances warrant, appraises AEC contractors as set forth in Chapter 0504, "Operational Safety Program Appraisals."

d. renders interpretations of the requirements of this chapter.

032 The Heads of Headquarters Divisions and Offices: assure that Headquarters employees, under their jurisdiction, comply with the provisions of this chapter.

033 Managers of Field Offices:*

a. assure that AEC and AEC contractor personnel and the general public are protected against radiation exposure in conformance with the provisions of this chapter.

b. assure that the necessary measurements are made to determine conformance with the requirements of this chapter.

c. request and justify specific exceptions for planned or anticipated deviations from the requirements of this chapter.

d. review and approve emergency plans for rescue and recovery operations.

e. act, where immediate decisions and actions are required, on requests for exceptions to the requirements of this chapter and immediately report and justify such action to the Division of Operational Safety, Headquarters. Contractors may be authorized to take all appropriate measures in emergency situations. See appendix 0524, IV, "Guidance for Emergency Exposure During Rescue and Recovery Activities."

0524-04 DEFINITIONS (as used in this chapter)

041 AEC contractor includes any AEC prime contractor or subcontractor exempt from, or not subject to, AEC licensing, except Part 115 Reactors, but subject to the contractual provisions of AECPR 9-7.5006-47 or modifications thereof.

042 Controlled area means any area, access to which is controlled for reasons of radiation safety.

043 Uncontrolled area means any area, access to which is not controlled for reasons of radiation safety.

*For purposes of this chapter, the Director, Division of Naval Reactors, and the Director, Division of Space Nuclear Systems, will assume the same responsibilities as Managers of Field Offices, for their respective program activities.

Approved: November 8, 1968

0524-05 BASIC REQUIREMENTS

051 Applicability The standards and instructions set forth in this chapter and appendix apply to, and shall be followed by, Headquarters Divisions and Offices, Field Offices, and AEC contractors, as defined in 041, above.

052 Coverage

a. These standards shall govern ionizing radiation exposure to AEC and AEC contractor personnel and to other individuals who may be exposed to ionizing radiation resulting from AEC and AEC contractor operations.

b. These standards do not apply to radiation exposures resulting from natural background, medical and dental procedures, nor do they apply to uncontrolled areas when activities involved are in the Plowshare Program[1] or are essential to national security such as the weapons testing program.

[1] Safety criteria of each Plowshare event will be considered on a case-by-case basis.

053 Exceptions to Chapter Requirements. Approval of the Division of Operational Safety must be obtained for any deviations from the requirements of this chapter or use of radiation protection standards different from those provided herein, except in emergency situations where immediate decisions and actions are required.

054 Appendix 0524 contains radiation protection standards which shall be applied in conformance with the requirements of this chapter. It also provides guidance for emergency exposure during rescue and recovery activities (IV).

055 References

a. Chapter 0525, "Occupational Radiation Exposure Information."

b. Chapter 0545, "Nuclear Accident Dosimetry Program."

0524-06 NATIONAL EMERGENCY APPLICATION

During a National Emergency, as defined in Chapter 0601-04, the provisions of this chapter and appendix are not mandatory.

I. INDIVIDUALS IN CONTROLLED AREAS

A. Radiation Protection Standards for External and Internal Exposure:

Type of Exposure	Condition	Dose (rem) or Dose Commitment
Whole body, head and trunk, active blood-forming organs, gonads, or lens of eye	Accumulated dose	5 (N-18)[1]
	Calendar quarter	3
Skin thyroid and bone[2]	Year	30
	Calendar quarter	10
Hands and forearms, feet and ankles	Year	75
	Calendar quarter	25
Other organs	Year	15
	Calendar quarter	5

To meet the above dose commitment standards, operations must be conducted in a manner that it will be unlikely that an individual will assimilate in a critical organ, due to exposure received in any calendar quarter (year) by inhalation, ingestion, or absorption, a quantity of a radionuclide that would commit the individual to a lifetime dose greater than is specified for a calendar quarter (year). (See table, above.)

B. Procedural Requirements

1. Restrictions

a. An individual employed at age 18, or an individual beyond age 18, who has received the maximum allowable radiation dose, shall not be exposed during the ensuing year to whole body doses exceeding:

(1) 1.25 rem for the first calendar quarter,

(2) 2.5 rem total for the first two calendar quarters,

(3) 3.75 rem total for the first three calendar quarters, and

(4) 5 rem for the year.

b. An individual under age 18 shall not be employed in, or allowed to enter, controlled areas in such manner that he will receive doses of radiation in amounts exceeding one-tenth the standards in A., above.

2. Combining Internal and External Dose. Whole-body internal dose from radionuclides for which the whole body is the critical organ must be combined with the external whole-body dose. Otherwise, the internal and external dose are not required to be added although reasonable effort should be made to minimize total organ dose.

3. Emergency or Accidental Exposure. The determination as to whether radiation doses received in emergency actions or accidental situations will be chargeable to the radiation exposure status of the individual will be made on a case-by-case basis by plant management in accordance with the advice of the plant health physics and occupational medical departments.

4. Monitoring Requirements. These requirements are applicable if the individual is likely to receive a dose or commitment in any calendar quarter in excess of 10 percent of the quarterly standards in A., above. due to:

a. external radiation - personnel monitoring equipment for each individual.

b. internal radiation - periodic (monthly, quarterly, annually, etc.) urinalyses and/or in vivo counting and/or evaluation of air concentrations to which the individual is exposed.

5. Methods of Estimating Dose Commitment. Methods of estimating dose commitment to the organ of interest should be suitable to the existing conditions and consistent with assumptions and recommendations of the Federal Radiation Council (FRC) and International Commission on Radiological Protection (ICRP).

[1] N equals the age in years at next birthday.
[2] An acceptable alternate standard for bone is the ICRP standard of 0.1 μ gram of radium-226 or its biological equivalent.

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Reprinted: February 4, 1969

C. Concentration Guides (CG's)

1. Air

CG's in Annex A, Table I, Column 1, were derived for the most part from the yearly standards in A., above (assume a 40-hour workweek). They should be used in evaluating the adequacy of health protection measures against airborne radioactivity in occupied areas.

2. Water

The CG's in Annex A, Table I, Column 2, are applicable to the discharge of liquid effluents to sanitary sewerage systems (see II, E., below). Drinking water concentrations in restricted areas shall be maintained within the CG's specified in Table II, Column 2.

II. INDIVIDUALS AND POPULATION GROUPS IN UNCONTROLLED AREAS

A. Radiation Protection Standards for External and Internal Exposure:

	Annual Dose or Dose Commitment (rem)	
Type of Exposure	Based on dose to critical individuals at points of maximum probable exposure	Based on an average dose to a suitable sample of the exposed population[1]
Whole body, gonads, or bone marrow	0.5	0.17
Other organs [2]	1.5	0.5

B. Procedural Requirements

Except as specified in C. 2., below, environmental and food chain monitoring and urinalysis or in vivo counting data shall be developed and used, as appropriate, to demonstrate compliance with the above standards and/or their equivalents (body burden, intake by ingestion and inhalation, or air and water concentrations at the point of intake) according to FRC and/or ICRP principles. Where the standards for individuals are used, exposure estimates should be confirmed by direct measurements such as personal dosimetry, excreta analysis, and in vivo counting. Surveillance over individual exposures need not be by urinalysis and in vivo counting if environmental and food chain monitoring sufficient to establish the range of individual exposure is performed and these exposure levels are known with comparable certainty. This demonstration should include a prerelease evaluation of probable exposures based on:

1. the radiological, chemical, physical, and biological properties of the effluent.
2. the locations of exposed individuals relative to the point of release.
3. the meteorology, soil chemistry, geology, hydrology, and related factors pertinent to the fate of the effluent.

[1] See Par. 5.4, FRC Report No. 1, for discussion on concept of suitable sample of exposed population.

[2] An acceptable alternate standard for bone for individuals is the ICRP standard of 0.003 μg of radium-226 or its biological equivalent. The alternate standard for populations would be one-third this ICRP standard.

C. Concentration Guides (CG's)

1. CG's in Annex A, Table II, were derived for the most part from the dose standards for individuals in A., above (assume 168 hours of exposure per week). These guides shall be reduced by a factor of three when applied to a suitable sample of the exposed population.
2. In situations in which it is not feasible or desirable to evaluate the exposure of individuals and samples of an exposed population to effluents as necessary to demonstrate compliance with the standards in A., above, effluent releases to uncontrolled areas shall be such that average concentrations of radioactivity at the point of release will not exceed the CG's in Table II. The point of release shall be considered to be the point at which the effluents pass beyond the site boundary. Radioactivity concentrations may be averaged over periods up to 1 year.

D. Further Limitations on Effluent Discharges

In any situation in which the effluents discharged by one or more activities of AEC, AEC contractors, or others cause exposures to approach the standards specified in A., above, appropriate effluent discharge limits may be set for these operations. In such cases, the manager of the field office may take the necessary corrective action if all activities concerned are within his area of responsibility. Otherwise, each case will be referred to the Director, Division of Operational Safety, for appropriate action including, where appropriate, coordination with actions taken by the Director of Regulation under 10 CFR 20.106(e).

E. Discharge to Sanitary Sewerage Systems

1. Effluents may be discharged to public sanitary systems provided:

   a. the quantity of radioactivity released in any 1 month, if diluted by the average monthly quantity of water released by the installation, will not result in an average concentration exceeding the CG in Annex A, Table I, Column 2., and

   b. the radiation protection standards in A., above, are not exceeded.

2. Concentrations or quantities of radioactive materials greater than those specified in 1.a. and b., above, may be released to chemical or sanitary sewerage systems owned by the Federal Government provided the standards in A., above, are not exceeded in uncontrolled areas.

III. QUALITY FACTORS TO BE APPLIED IN DETERMINING REM EXPOSURE

The exposure standards specified in this appendix are expressed in terms of rem, which implies that the absorbed dose (expressed in rads) should be multiplied by an appropriate weighting factor (quality factor (QF)). The QF's to be used for determining neutron and/or proton exposures from known energies are provided in the following table:

Energy of Neutrons or Protons	Quality Factors	
MeV	Neutrons	Protons
Thermal	3	
0.0001	2	
0.005	2.5	
0.02	5	
0.1	8	
0.5	10	
1.0	10	
2.5	8	
5.0	7	
7.5	7	
10	7	
20	6	
30	6	
50	5	1
100	5	1.5
200	4	1.5
300	4	2
500	4	3
700	3	3
1000	3	3

IV. GUIDANCE FOR EMERGENCY EXPOSURE DURING RESCUE AND RECOVERY ACTIVITIES

A. Purpose

The emergency action guidance promulgated in this part provides instructions and background information for use in determining appropriate actions concerning the rescue and recovery of persons and the protection of health and property during periods of emergency.

B. General Considerations

1. The problem of controlling exposure to radiation during rescue and recovery actions is extremely complex.

Performing rescue and recovery operations requires the exercise of prompt judgment to take into account multiple hazards and alternate methods of accomplishment. Sound judgment and flexibility of action are crucial to the success of any type of emergency actions. Although the guiding principle is to minimize the risk of injury to those persons involved in the rescue and recovery activities, the control of radiation exposures should be consistent with the immediate objective of saving human life, the recovery of a deceased victim, and/or the protecting of health and saving of property.*

2. To preclude the possibility of unnecessarily restricting action that may be necessary to save lives, these instructions do not establish a rigid upper limit of exposure but rather leave judgment up to persons in charge of emergency operations to determine the amount of exposures that should be permitted to perform the emergency mission.

3. The official in charge must carefully examine any proposed action involving further radiation exposure by weighing the risks of radiation insults, actual or potential, against the benefits to be gained. Exposure probability, biological consequences related to dose, and the number of people involved are the essential elements to be evaluated in making a risk determination.

4. These instructions recognize that accident situations involving the saving of lives will require separate criteria from that of actions required to recover deceased victims or saving of property. In the latter instances, the amount of exposure expected to be received by persons should be controlled as much as possible within occupational limits.

C. Emergency Situations

Specific dose criteria and judgment factors are set forth for the three categories of risk-benefit considerations, i.e., actions involving the saving of human life, the recovery of deceased victims, and the protection of health and property.

*The determination as to whether radiation dosage received in emergency actions will be chargeable to the radiation exposure status of the persons will be made on an individual case basis.

1. Saving of Human Life

a. To preclude the possibility of unnecessarily restricting action that may be necessary to save lives, judgment shall be left to persons in charge of emergency operations to determine the amount of exposures that should be permitted to perform the emergency mission.

b. Attempts to rescue victims of a nuclear incident should be regarded in the same context as any other emergency action involving the rescue of victims, regardless of the type of hazard involved.

c. Where there is reasonable expectation that an individual is alive within the affected area, the course of action to be pursued should be determined by the person onsite having the emergency action responsibility.

d. The amount of exposure for this type of emergency action shall be determined by the person onsite having the emergency action responsibility. He should immediately evaluate the situation and establish the exposure limit for the rescue mission accordingly. His judgment should be based upon:

(1) evaluation of the inherent risks by considering:

(a) the reliability of the prediction of radiation injury. This reliability cannot be any greater than reliability of the estimation of the dose. Therefore, consideration should be given to limits of error associated with the specific instruments and techniques used to estimate the dose rate. This is especially crucial when the estimated dose approximates 100 rems or more.

(b) the exposure expected in performing the action shall be weighed in terms of the effects of acute external whole-body exposure and entry of radioactive material into the body.

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(2) current assessment of the degree and nature of the hazard, and the capability of reducing inherent risk from that hazard through appropriate mechánism such as the use of protective equipment, remote manipulation equipment, or similar means.

e. In the course of making a decision to perform the action, the risk to rescue personnel should be weighed against the probability of success of the rescue action.

f. Any rescue action that may involve substantial personal risk should be performed by volunteers, and each emergency worker shall be advised of the known or estimated extent of such risk prior to participation.

2. Recovery of Deceased Victims

a. Accident situations involving recovery of deceased victims require criteria separate from those for saving lives. Since the element of time is no longer a critical factor, the recovery of deceased victims should be well planned. The amount of radiation exposure received by persons in recovery operations shall be controlled within existing occupational exposure guides.

b. In those situations where the bodies are located in areas inaccessible because of high direct radiation fields, and where the recovery mission would result in exposure in excess of occupational exposure standards contained in this appendix, special remote recovery devices should be used to retrieve the bodies.

c. In special circumstances where it is impossible to recover bodies without the entry of emergency workers into the area, the individual in charge of the recovery mission may determine it necessary to exceed the occupational exposure standards contained in this appendix. The planned exposures of an individual participating in the recovery should not exceed 12 rem total for the year or 5 (N-18), whichever is the more limiting.

3. Protection of Health and Property

a. Where the risk (probability and magnitude) of the radiation hazard either bears significantly on the state of health of people or may result in loss of property, so that immediate remedial action is required, the following criteria should apply:

(1) When the person in charge of emergency action onsite deems it essential to reduce a hazard potential to acceptable levels or to prevent a substantial loss of property, a planned exposure up to, but not to exceed, 12 rem for the year or 5 (N-18), whichever is more limiting, may be received by individuals participating in the operation.

However, the person in charge of emergency action at the incident scene may elect, under special circumstances, to waive these limits and permit volunteers to receive an exposure up to, but not to exceed, 25 rem.

(2) Where the potential risk of radiation hazard following the nuclear incident is such that life would be in jeopardy, or that there would be severe effects on health of the public or loss of property inimicable to the public safety, the criteria for the saving of human life shall apply.

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ANNEX A

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Controlled Area		Table II Uncontrolled Area	
			Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Actinium (89)	Ac 227	S	2×10^{-12}	6×10^{-4}	8×10^{-14}	2×10^{-6}
		I	3×10^{-11}	9×10^{-3}	9×10^{-13}	3×10^{-4}
	Ac 228	S	8×10^{-8}	3×10^{-3}	3×10^{-9}	9×10^{-5}
		I	2×10^{-8}	3×10^{-3}	6×10^{-10}	9×10^{-5}
Americium (95)	Am 241	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	2×10^{-5}
	Am 242m	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	3×10^{-10}	3×10^{-3}	9×10^{-12}	9×10^{-5}
	Am 242	S	4×10^{-8}	4×10^{-3}	1×10^{-9}	1×10^{-4}
		I	5×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Am 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 244	S	4×10^{-6}	1×10^{-1}	1×10^{-7}	5×10^{-3}
		I	2×10^{-5}	1×10^{-1}	8×10^{-7}	5×10^{-3}
Antimony (51)	Sb 122	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
	Sb 124	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	2×10^{-8}	7×10^{-4}	7×10^{-10}	2×10^{-5}
	Sb 125	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	3×10^{-8}	3×10^{-3}	9×10^{-10}	1×10^{-4}
Argon (18)	A 37	Sub[2]	6×10^{-3}	....	1×10^{-4}	....
	A 41	Sub	2×10^{-6}	....	4×10^{-8}	....
Arsenic (33)	As 73	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	5×10^{-4}
		I	4×10^{-7}	1×10^{-2}	1×10^{-8}	1×10^{-4}
	As 74	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	1×10^{-7}	2×10^{-3}	4×10^{-9}	5×10^{-5}
	As 76	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	As 77	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Astatine (85)	At 211	S	7×10^{-9}	5×10^{-5}	2×10^{-10}	2×10^{-6}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
Barium (56)	Ba 131	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ba 140	S	1×10^{-7}	8×10^{-4}	4×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	2×10^{-5}
Berkelium (97)	Bk 249	S	9×10^{-10}	2×10^{-2}	3×10^{-11}	6×10^{-4}
		I	1×10^{-7}	2×10^{-2}	4×10^{-9}	6×10^{-4}
	Bk 250	S	1×10^{-7}	6×10^{-3}	5×10^{-9}	2×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Beryllium (4)	Be 7	S	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	1×10^{-6}	5×10^{-2}	4×10^{-8}	2×10^{-3}
Bismuth (83)	Bi 206	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	1×10^{-7}	1×10^{-3}	5×10^{-9}	4×10^{-5}
	Bi 207	S	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
		I	1×10^{-8}	2×10^{-3}	5×10^{-10}	6×10^{-5}
	Bi 210	S	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
		I	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Bi 212	S	1×10^{-7}	1×10^{-2}	3×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	7×10^{-9}	4×10^{-4}
Bromine (35)	Br 82	S	1×10^{-6}	8×10^{-3}	4×10^{-8}	3×10^{-4}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Cadmium (48)	Cd 109	S	5×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
		I	7×10^{-8}	5×10^{-3}	3×10^{-9}	2×10^{-4}

[1] See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND--continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]			Table I Controlled Area		Table II Uncontrolled Area	
				Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Cadmium (48)–Continued	Cd	115m	S	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
			I	4×10^{-5}	7×10^{-4}	1×10^{-9}	3×10^{-5}
	Cd	115	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
			I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Calcium (20)	Ca	45	S	3×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
			I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Ca	47	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
			I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
Californium (98)	Cf	249	S	2×10^{-12}	1×10^{-4}	5×10^{-14}	4×10^{-6}
			I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cf	250	S	5×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
			I	1×10^{-10}	7×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf	251	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
			I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf	252	S	2×10^{-11}	7×10^{-4}	7×10^{-13}	2×10^{-5}
			I	1×10^{-10}	7×10^{-4}	4×10^{-12}	2×10^{-5}
	Cf	253	S	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
			I	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
	Cf	254	S	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
			I	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
Carbon (6)	C	14	S	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
	(CO_2)		Sub	5×10^{-5}	....	1×10^{-6}	....
Cerium (58)	Ce	141	S	4×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
			I	2×10^{-7}	3×10^{-3}	5×10^{-9}	9×10^{-5}
	Ce	143	S	3×10^{-7}	1×10^{-3}	9×10^{-9}	4×10^{-5}
			I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	Ce	144	S	1×10^{-8}	3×10^{-4}	3×10^{-10}	1×10^{-5}
			I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Cesium (55)	Cs	131	S	1×10^{-5}	7×10^{-2}	4×10^{-7}	2×10^{-3}
			I	3×10^{-6}	3×10^{-2}	1×10^{-7}	9×10^{-4}
	Cs	134m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
			I	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Cs	134	S	4×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
			I	1×10^{-8}	1×10^{-3}	4×10^{-10}	4×10^{-5}
	Cs	135	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	9×10^{-8}	7×10^{-3}	3×10^{-9}	2×10^{-4}
	Cs	136	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
			I	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
	Cs	137	S	6×10^{-8}	4×10^{-4}	2×10^{-9}	2×10^{-5}
			I	1×10^{-8}	1×10^{-3}	5×10^{-10}	4×10^{-5}
Chlorine (17)	Cl	36	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
			I	2×10^{-8}	2×10^{-3}	8×10^{-10}	6×10^{-5}
	Cl	38	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
			I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
Chromium (24)	Cr	51	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
			I	2×10^{-6}	5×10^{-2}	8×10^{-8}	2×10^{-3}
Cobalt (27)	Co	57	S	3×10^{-6}	2×10^{-2}	1×10^{-7}	5×10^{-4}
			I	2×10^{-7}	1×10^{-2}	6×10^{-9}	4×10^{-4}
	Co	58m	S	2×10^{-5}	8×10^{-2}	6×10^{-7}	3×10^{-3}
			I	9×10^{-6}	6×10^{-2}	3×10^{-7}	2×10^{-3}
	Co	58	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	5×10^{-8}	3×10^{-3}	2×10^{-9}	9×10^{-5}
	Co	60	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
			I	9×10^{-9}	1×10^{-3}	3×10^{-10}	3×10^{-5}

[1] See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND--continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Controlled Area		Table II Uncontrolled Area	
			Column 1 Air ($\mu c/ml$)	Column 2 Water ($\mu c/ml$)	Column 1 Air ($\mu c/ml$)	Column 2 Water ($\mu c/ml$)
Copper (29)	Cu 64	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Curium (96)	Cm 242	S	1×10^{-10}	7×10^{-4}	4×10^{-12}	2×10^{-5}
		I	2×10^{-10}	7×10^{-4}	6×10^{-12}	3×10^{-5}
	Cm 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	5×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cm 244a	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cm 245	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 246	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 247	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	6×10^{-4}	4×10^{-12}	2×10^{-5}
	Cm 248	S	6×10^{-13}	1×10^{-5}	2×10^{-14}	4×10^{-7}
		I	1×10^{-11}	4×10^{-5}	4×10^{-13}	1×10^{-6}
	Cm 249	S	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
		I	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
Dysprosium (66)	Dy 165	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
	Dy 166	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Einsteinium (99)	Es 253	S	8×10^{-10}	7×10^{-4}	3×10^{-11}	2×10^{-5}
		I	6×10^{-10}	7×10^{-4}	2×10^{-11}	2×10^{-5}
	Es 254m	S	5×10^{-9}	8×10^{-4}	2×10^{-10}	2×10^{-5}
		I	6×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
	Es 254	S	2×10^{-11}	4×10^{-4}	6×10^{-13}	1×10^{-5}
		I	1×10^{-10}	4×10^{-4}	4×10^{-12}	1×10^{-5}
	Es 255	S	5×10^{-10}	5×10^{-4}	2×10^{-11}	3×10^{-5}
		I	4×10^{-10}	8×10^{-4}	1×10^{-11}	3×10^{-4}
Erbium (68)	Er 169	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	Er 171	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Europium (63)	Eu 152	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	(T/2=9.2 hrs)	I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Eu 152	S	1×10^{-8}	2×10^{-3}	4×10^{-10}	8×10^{-5}
	(T/2=13 yrs)	I	2×10^{-8}	2×10^{-3}	6×10^{-10}	8×10^{-5}
	Eu 154	S	4×10^{-9}	6×10^{-4}	1×10^{-10}	2×10^{-5}
		I	7×10^{-9}	6×10^{-4}	2×10^{-10}	2×10^{-5}
	Eu 155	S	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
		I	7×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
Fermium (100)	Fm 254	S	6×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
		I	7×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Fm 255	S	2×10^{-8}	1×10^{-3}	6×10^{-10}	3×10^{-5}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	3×10^{-5}
	Fm 256	S	3×10^{-9}	3×10^{-5}	1×10^{-10}	9×10^{-7}
		I	2×10^{-9}	3×10^{-5}	6×10^{-11}	9×10^{-7}
Fluorine (9)	F 18	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
Gadolinium (64)	Gd 153	S	2×10^{-7}	6×10^{-3}	8×10^{-9}	2×10^{-4}
		I	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Gd 159	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}

[1] See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND--continued
(See notes at end of annex)

Element (atomic number)	Isotope[1]			Table I Controlled Area		Table II Uncontrolled Area	
				Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Gallium (31)	Ga	72	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
			I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Germanium (32)	Ge	71	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
			I	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
Gold (79)	Au	196	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
			I	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
	Au	198	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
			I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Au	199	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
			I	8×10^{-7}	4×10^{-3}	3×10^{-8}	2×10^{-4}
Hafnium (72)	Hf	181	S	4×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
			I	7×10^{-8}	2×10^{-3}	3×10^{-9}	7×10^{-5}
Holmium (67)	Ho	166	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
			I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Hydrogen (1)	H	3	S	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
			I	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
			Sub	2×10^{-3}	....	4×10^{-5}	....
Indium (49)	In	113m	S	8×10^{-6}	4×10^{-2}	3×10^{-7}	1×10^{-3}
			I	7×10^{-6}	4×10^{-2}	2×10^{-7}	1×10^{-3}
	In	114m	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
			I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
	In	115m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
			I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	In	115	S	2×10^{-7}	3×10^{-3}	9×10^{-9}	9×10^{-5}
			I	3×10^{-8}	3×10^{-3}	1×10^{-9}	9×10^{-5}
Iodine (53)*	I	125	S	5×10^{-9}	4×10^{-5}	8×10^{-11}	2×10^{-7}
			I	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
	I	126	S	8×10^{-9}	5×10^{-5}	9×10^{-11}	3×10^{-7}
			I	3×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	I	129	S	2×10^{-9}	1×10^{-5}	2×10^{-11}	6×10^{-8}
			I	7×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
	I	131	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
			I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	I	132	S	2×10^{-7}	2×10^{-3}	3×10^{-9}	8×10^{-6}
			I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	I	133	S	3×10^{-8}	2×10^{-4}	4×10^{-10}	1×10^{-6}
			I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	I	134	S	5×10^{-7}	4×10^{-3}	6×10^{-9}	2×10^{-5}
			I	3×10^{-6}	2×10^{-2}	1×10^{-7}	6×10^{-4}
	I	135	S	1×10^{-7}	7×10^{-4}	1×10^{-9}	4×10^{-6}
			I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Iridium (77)	Ir	190	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
			I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ir	192	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	4×10^{-5}
			I	3×10^{-8}	1×10^{-3}	9×10^{-10}	4×10^{-5}
	Ir	194	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
			I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
Iron (26)	Fe	55	S	9×10^{-7}	2×10^{-2}	3×10^{-8}	8×10^{-4}
			I	1×10^{-6}	7×10^{-2}	3×10^{-8}	2×10^{-3}
	Fe	59	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
			I	5×10^{-9}	2×10^{-3}	2×10^{-9}	5×10^{-5}
Krypton[2] (36)	Kr	85m	Sub	6×10^{-6}	....	1×10^{-7}	....
	Kr	85	Sub	1×10^{-5}	....	3×10^{-7}	....

* In the derivation of the concentration guides for soluble forms of iodine in table II, a 2 gram thyroid (infants) and daily intakes of 3×10^{6} ml of air and 1×10^{3} ml of water (fluid water plus water contents of foods) assumed.

[1] See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND--continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]			Table I Controlled Area		Table II Uncontrolled Area	
				Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Krypton[2] (36)--Continued	Kr	87	Sub	1×10^{-6}	....	2×10^{-8}	....
	Kr	88	Sub	1×10^{-6}	....	2×10^{-8}	....
Lanthanum (57)	La	140	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
			I	1×10^{-7}	7×10^{-4}	4×10^{-9}	2×10^{-5}
Lead (82)	Pb	203	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
			I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	Pb	210	S	1×10^{-10}	4×10^{-6}	4×10^{-12}	1×10^{-7}
			I	2×10^{-10}	5×10^{-3}	8×10^{-12}	2×10^{-4}
	Pb	212	S	2×10^{-8}	6×10^{-4}	6×10^{-10}	2×10^{-5}
			I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
Lutetium (71)	Lu	177	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Manganese (25)	Mn	52	S	2×10^{-7}	1×10^{-3}	7×10^{-9}	3×10^{-5}
			I	1×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Mn	54	S	4×10^{-7}	4×10^{-3}	1×10^{-8}	1×10^{-4}
			I	4×10^{-8}	3×10^{-3}	1×10^{-9}	1×10^{-4}
	Mn	56	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Mercury (80)	Hg	197m	S	7×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-4}
			I	8×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Hg	197	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
			I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
	Hg	203	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
			I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
Molybdenum (42)	Mo	99	S	7×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
			I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Neodymium (60)	Nd	144	S	8×10^{-11}	2×10^{-3}	3×10^{-12}	7×10^{-5}
			I	3×10^{-10}	2×10^{-3}	1×10^{-11}	8×10^{-5}
	Nd	147	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
			I	2×10^{-7}	2×10^{-3}	8×10^{-9}	6×10^{-5}
	Nd	149	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
			I	1×10^{-6}	8×10^{-3}	5×10^{-8}	3×10^{-4}
Neptunium (93)	Np	237	S	4×10^{-12}	9×10^{-5}	1×10^{-13}	3×10^{-6}
			I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	Np	239	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	7×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
Nickel (28)	Ni	59	S	5×10^{-7}	6×10^{-3}	2×10^{-8}	2×10^{-4}
			I	8×10^{-7}	6×10^{-2}	3×10^{-8}	2×10^{-3}
	Ni	63	S	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
			I	3×10^{-7}	2×10^{-2}	1×10^{-8}	7×10^{-4}
	Ni	65	S	9×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Niobium (Columbium) (41)	Nb	93m	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	4×10^{-4}
			I	2×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Nb	95	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	1×10^{-7}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Nb	97	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
			I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
Osmium (76)	Os	185	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
			I	5×10^{-8}	2×10^{-3}	2×10^{-9}	7×10^{-5}
	Os	191m	S	2×10^{-5}	7×10^{-2}	6×10^{-7}	3×10^{-3}
			I	9×10^{-6}	7×10^{-2}	3×10^{-7}	2×10^{-3}
	Os	191	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
			I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Os	193	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
			I	3×10^{-7}	2×10^{-3}	9×10^{-9}	5×10^{-5}

[1] See footnotes at end of table.

Approved: November 8, 1968

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND--continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Controlled Area		Table II Uncontrolled Area	
			Column 1 Air ($\mu c/ml$)	Column 2 Water ($\mu c/ml$)	Column 1 Air ($\mu c/ml$)	Column 2 Water ($\mu c/ml$)
Palladium (46)	Pd 103	S	1×10^{-6}	1×10^{-2}	5×10^{-8}	3×10^{-4}
		I	7×10^{-7}	8×10^{-3}	3×10^{-8}	3×10^{-4}
	Pd 109	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Phosphorus (15)	P 32	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	8×10^{-8}	7×10^{-4}	3×10^{-9}	2×10^{-5}
Platinum (78)	Pt 191	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Pt 193m	S	7×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Pt 197m	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
	Pt 197	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Plutonium (94)	Pu 238	S	2×10^{-12}	1×10^{-4}	7×10^{-14}	5×10^{-6}
		I	3×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 239	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 240	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 241	S	9×10^{-11}	7×10^{-3}	3×10^{-12}	2×10^{-4}
		I	4×10^{-8}	4×10^{-2}	1×10^{-9}	1×10^{-3}
	Pu 242	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	9×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 243	S	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
		I	2×10^{-6}	1×10^{-2}	8×10^{-8}	3×10^{-4}
	Pu 244	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	3×10^{-11}	3×10^{-4}	1×10^{-12}	1×10^{-5}
Polonium (84)	Po 210	S	5×10^{-10}	2×10^{-5}	2×10^{-11}	7×10^{-7}
		I	2×10^{-10}	8×10^{-4}	7×10^{-12}	3×10^{-5}
Potassium (19)	K 42	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
		I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Praseodymium (59)	Pr 142	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Pr 143	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
Promethium (61)	Pm 147	S	6×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
		I	1×10^{-7}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Pm 149	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Protoactinium (91)	Pa 230	S	2×10^{-9}	7×10^{-3}	6×10^{-11}	2×10^{-4}
		I	8×10^{-10}	7×10^{-3}	3×10^{-11}	2×10^{-4}
	Pa 231	S	1×10^{-12}	3×10^{-5}	4×10^{-14}	9×10^{-7}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	2×10^{-5}
	Pa 233	S	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
		I	2×10^{-7}	3×10^{-3}	6×10^{-9}	1×10^{-4}
*Radium (88)	Ra 223	S	2×10^{-9}	2×10^{-5}	6×10^{-11}	7×10^{-7}
		I	2×10^{-10}	1×10^{-4}	8×10^{-12}	4×10^{-6}
	Ra 224	S	5×10^{-9}	7×10^{-5}	2×10^{-10}	2×10^{-6}
		I	7×10^{-10}	2×10^{-4}	2×10^{-11}	5×10^{-6}
	Ra 226	S	3×10^{-11}	4×10^{-7}	3×10^{-12}	3×10^{-8}
		I	5×10^{-11}	9×10^{-4}	2×10^{-12}	3×10^{-5}
	Ra 228	S	7×10^{-11}	8×10^{-7}	2×10^{-12}	3×10^{-8}
		I	4×10^{-11}	7×10^{-4}	1×10^{-12}	3×10^{-5}
Radon (86)	Rn 220	S	3×10^{-7}	....	1×10^{-8}	....
		I	....	....	....	....
	Rn 222	S	1×10^{-7}	....	3×10^{-9}	....

See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND--continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Controlled Area		Table II Uncontrolled Area	
			Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Rhenium (75)	Re 183	S	3×10^{-6}	2×10^{-2}	9×10^{-8}	6×10^{-4}
		I	2×10^{-7}	8×10^{-3}	5×10^{-9}	3×10^{-4}
	Re 186	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Re 187	S	9×10^{-6}	7×10^{-2}	3×10^{-7}	3×10^{-3}
		I	5×10^{-7}	4×10^{-2}	2×10^{-8}	2×10^{-3}
	Re 188	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Rhodium (45)	Rh 103m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
		I	6×10^{-5}	3×10^{-1}	2×10^{-6}	1×10^{-2}
	Rh 105	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Rubidium (37)	Rb 86	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	7×10^{-8}	7×10^{-4}	2×10^{-9}	2×10^{-5}
	Rb 87	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	7×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
Ruthenium (44)	Ru 97	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
	Ru 103	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	8×10^{-8}	2×10^{-3}	3×10^{-9}	8×10^{-5}
	Ru 105	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Ru 106	S	8×10^{-8}	4×10^{-4}	3×10^{-9}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Samarium (62)	Sm 147	S	7×10^{-11}	2×10^{-3}	2×10^{-12}	6×10^{-5}
		I	3×10^{-10}	2×10^{-3}	9×10^{-12}	7×10^{-5}
	Sm 151	S	6×10^{-8}	1×10^{-2}	2×10^{-9}	4×10^{-4}
		I	1×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Sm 153	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Scandium (21)	Sc 46	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	8×10^{-10}	4×10^{-5}
	Sc 47	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
	Sc 48	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Selenium (34)	Se 75	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	1×10^{-7}	8×10^{-3}	4×10^{-9}	3×10^{-4}
Silicon (14)	Si 31	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	1×10^{-6}	6×10^{-3}	3×10^{-8}	2×10^{-4}
Silver (47)	Ag 105	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	8×10^{-8}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Ag 110m	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	1×10^{-8}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Ag 111	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Sodium (11)	Na 22	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	9×10^{-9}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Na 24	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Strontium (38)	Sr 85m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
		I	3×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
	Sr 85	S	2×10^{-7}	3×10^{-3}	8×10^{-9}	1×10^{-4}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Sr 89	S	3×10^{-8}	3×10^{-4}	3×10^{-10}	3×10^{-6}

[1] See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND--continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]			Table I Controlled Area		Table II Uncontrolled Area	
				Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Strontium (38)—Continued			I	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
	Sr	90	S	1×10^{-9}	1×10^{-5}	3×10^{-11}	3×10^{-7}
			I	5×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Sr	91	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
			I	3×10^{-7}	1×10^{-3}	9×10^{-9}	5×10^{-5}
	Sr	92	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
			I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Sulfur (16)	S	35	S	3×10^{-7}	2×10^{-3}	9×10^{-9}	6×10^{-5}
			I	3×10^{-7}	8×10^{-3}	9×10^{-9}	3×10^{-4}
Tantalum (73)	Ta	182	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
			I	2×10^{-8}	1×10^{-3}	7×10^{-10}	4×10^{-5}
Technetium (43)	Tc	96m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
			I	3×10^{-5}	3×10^{-1}	1×10^{-6}	1×10^{-2}
	Tc	96	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Tc	97m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
			I	2×10^{-7}	5×10^{-3}	5×10^{-9}	2×10^{-4}
	Tc	97	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
			I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
	Tc	99m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
			I	1×10^{-5}	8×10^{-2}	5×10^{-7}	3×10^{-3}
	Tc	99	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
			I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
Tellurium (52)	Te	125m	S	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
			I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
	Te	127m	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
			I	4×10^{-8}	2×10^{-3}	1×10^{-9}	5×10^{-5}
	Te	127	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
			I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Te	129m	S	8×10^{-8}	1×10^{-3}	3×10^{-9}	3×10^{-5}
			I	3×10^{-8}	6×10^{-4}	1×10^{-9}	2×10^{-5}
	Te	129	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
			I	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
	Te	131m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
			I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
	Tc	132	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
			I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Terbium (65)	Tb	160	S	1×10^{-7}	1×10^{-3}	3×10^{-9}	4×10^{-5}
			I	3×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
Thallium (81)	Tl	200	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
			I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
	Tl	201	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
			I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Tl	202	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	2×10^{-7}	2×10^{-3}	8×10^{-9}	7×10^{-5}
	Tl	204	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	3×10^{-8}	2×10^{-3}	9×10^{-10}	6×10^{-5}
Thorium (90)	Th	228	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
			I	6×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
	Th	230	S	2×10^{-12}	5×10^{-5}	8×10^{-14}	2×10^{-6}
			I	1×10^{-11}	9×10^{-4}	3×10^{-13}	3×10^{-5}
	Th	232	S	3×10^{-11}	5×10^{-5}	1×10^{-12}	2×10^{-6}
			I	3×10^{-11}	1×10^{-3}	1×10^{-12}	4×10^{-5}

[1] See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND--continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Controlled Area		Table II Uncontrolled Area	
			Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Thorium (90)—Continued	Th natural*	S	3×10^{-11}	3×10^{-5}	1×10^{-12}	1×10^{-6}
		I	3×10^{-11}	3×10^{-4}	1×10^{-12}	1×10^{-5}
	Th 234	S	6×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	3×10^{-8}	5×10^{-4}	1×10^{-9}	2×10^{-5}
Thulium (69)	Tm 170	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
		I	3×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
	Tm 171	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	5×10^{-4}
		I	2×10^{-7}	1×10^{-2}	8×10^{-9}	5×10^{-4}
Tin (50)	Sn 113	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	8×10^{-5}
	Sn 125	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	8×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Tungsten (Wolfram) (74)	W 181	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	1×10^{-7}	1×10^{-2}	4×10^{-9}	3×10^{-4}
	W 185	S	8×10^{-7}	1×10^{-3}	3×10^{-8}	1×10^{-4}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-5}
	W 187	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-3}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Uranium (92)	U 230	S	3×10^{-10}	1×10^{-4}	1×10^{-11}	5×10^{-6}
		I	1×10^{-10}	1×10^{-4}	4×10^{-12}	5×10^{-6}
	U 232	S	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
		I	3×10^{-11}	8×10^{-4}	9×10^{-13}	3×10^{-5}
	U 233	S	5×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	U 234	S	6×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	U 235	S	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	U 236	S	6×10^{-10}	1×10^{-3}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	1×10^{-3}	4×10^{-12}	3×10^{-5}
	U 238	S	7×10^{-11}	1×10^{-3}	3×10^{-12}	4×10^{-5}
		I	1×10^{-10}	1×10^{-3}	5×10^{-12}	4×10^{-5}
	U 240	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
	U-natural**	S	7×10^{-11}	5×10^{-4}	3×10^{-12}	2×10^{-5}
		I	6×10^{-11}	5×10^{-4}	2×10^{-12}	2×10^{-5}
Vanadium (23)	V 48	S	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
		I	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
Xenon (54)	Xe 131m	Sub	2×10^{-5}	....	4×10^{-7}	....
	Xe 133	Sub	1×10^{-5}	....	3×10^{-7}	....
	Xe 133m	Sub	1×10^{-5}	....	3×10^{-7}	....
	Xe 135	Sub	4×10^{-6}	....	1×10^{-7}	....
Ytterbium (70)	Yb 175	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Yttrium (39)	Y 90	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	Y 91m	S	2×10^{-5}	1×10^{-1}	8×10^{-7}	3×10^{-3}
		I	2×10^{-5}	1×10^{-1}	6×10^{-7}	3×10^{-3}
	Y 91	S	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
		I	3×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}

*A curie of natural thorium means the sum of 3.7×10^{10} dis/sec from Th 232 plus 3.7×10^{10} dis/sec from Th 228. One curie of natural thorium is equivalent to 9,000 kilograms or 19, 850 pounds of natural thorium.

**A curie of natural uranium means the sum of $3.7\text{X}10^{10}$ disintegrations per second from U 238 plus $3.7\text{X}10^{10}$ dis/sec from U 234 plus $9\text{X}10^{8}$ dis/sec from U 235. One curie of natural uranium is equivalent to 3,000 kilograms or 6,615 pounds of natural uranium.

[1] See footnotes at end of table.

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND--continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]			Table I Controlled Area		Table II Uncontrolled Area	
				Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
Yttrium (39) Continued	Y	92	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
			I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Y	93	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
			I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Zinc (30)	Zn	65	S	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
			I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
	Zn	69m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
			I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Zn	69	S	7×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
			I	9×10^{-6}	5×10^{-2}	3×10^{-7}	2×10^{-3}
Zirconium (40)	Zr	93	S	1×10^{-7}	2×10^{-2}	4×10^{-9}	8×10^{-4}
			I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
	Zr	95	S	1×10^{-7}	2×10^{-3}	4×10^{-9}	6×10^{-5}
			I	3×10^{-8}	2×10^{-3}	1×10^{-9}	6×10^{-5}
	Zr	97	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
			I	9×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than 2 hours.			Sub	1×10^{-6}	....	3×10^{-8}	....
Any single radionuclide, not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than 2 hours.				3×10^{-9}	9×10^{-5}	1×10^{-10}	3×10^{-6}
Any single radionuclide, not listed above, which decays by alpha emission or spontaneous fission.				6×10^{-13}	4×10^{-7}	2×10^{-14}	3×10^{-8}

[1] Soluble (S); Insoluble (I).
[2] "Sub" means that values given are for submersion in a semispherical infinite cloud of airborne material.

NOTE: In any case where there is a mixture in air or water of more than one radionuclide, the guide values, for purposes of this annex, should be determined as follows:

1. If the identity and concentration of each radionuclide in the mixture are known, the limiting values should be derived as follows: Determine, for each radionuclide in the mixture, the ratio between the quantity present in the mixture and the guide otherwise established in this annex for the specific radionuclide when not in a mixture. The sum of such ratios for all the radionuclides in the mixture shall not exceed "1" (i.e., "unity").

EXAMPLE: If radionuclides A, B, and C are present in concentrations C_A, C_B, and C_C, and if the applicable CG's are CG_A, CG_B and CG_C respectively, then the concentrations should be limited so that the following relationship exists:

$$\frac{C_A}{CG_A} + \frac{C_B}{CG_B} + \frac{C_C}{CG_C} \leq 1$$

2. If either the identity or the concentration of any radionuclide in the mixture is not known, the guide values for purposes of this annex shall be:

   a. for purposes of Table I, Col. 1 - 6×10^{-12}

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b. for purposes of Table I, Col. 2 - 4×10^{-7}

c. for purposes of Table II, Col. 1 - 2×10^{-14}

d. for purposes of Table II, Col. 2 - 3×10^{-8}

3. If any of the conditions specified below are met, the corresponding values specified below may be used in lieu of those specified in 2., above.

a. If the identity of each radionuclide in the mixture is known but the concentration of one or more of the radionuclides in the mixture is not known, the concentration guide for the mixture is the guide specified in this annex for the radionuclide in the mixture having the lowest concentration guide, or

b. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in this annex are not present in the mixture, the concentration guide for the mixture is the lowest concentration guide specified in this annex for any radionuclide which is not known to be absent from the mixture; or

c.

Element (atomic number) and isotope	Table I Controlled Area		Table II Uncontrolled Area	
	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)	Column 1 Air (μc/ml)	Column 2 Water (μc/ml)
If it is known that Sr 90, I 125, I 126, I 129, I 131, (I 133, table II only), Pb 210, Po 210, At 211, Ra 223, Ra 224, Ra 226, Ac 227, Ra 228, Th 230, Pa 231, Th 232, Th-nat, Cm 248, Cf 254, and Fm 256 are not present ---	-------	9×10^{-5}	-------	3×10^{-6}
If it is known that Sr 90, I 125, I 126, I 129, (I 131, I 133, table II only), Pb 210, Po 210, Ra 223, Ra 226, Ra 228, Pa 231, Th-nat, Cm 248, Cf 254, and Fm 256 are not present -------------------	-------	6×10^{-5}	-------	2×10^{-6}
If it is known that Sr 90, I 129, (I 125, I 126, I 131, table II only), Pb 210, Ra 226, Ra 228, Cm 248, and Cf 254 are not present -----------------	-------	2×10^{-5}	-------	6×10^{-7}
If it is known that (I 129, table II only), Ra 226, and Ra 228 are not present -------------------	-------	3×10^{-6}	-------	1×10^{-7}
If it is known that alpha-emitters and Sr 90, I 129, Pb 210, Ac 227, Ra 228, Pa 230, Pu 241, and Bk 249 are not present -------------------	3×10^{-9}	------	1×10^{-10}	------
If it is known that alpha-emitters and Pb 210, Ac 227, Ra 228, and Pu 241 are not present------------	3×10^{-10}	------	1×10^{-11}	------
If it is known that alpha-emitters and Ac 227 are not present ----------------------------	3×10^{-11}	------	1×10^{-12}	------
If it is known that Ac 227, Th 230, Pa 231, Pu 238, Pu 239, Pu 240, Pu 242, Pu 244, Cm 248, Cf 249 and Cf 251 are not present -------------------	3×10^{-12}	------	1×10^{-13}	------

4. If the mixture of radionuclides consists of uranium and its daughter products in ore dust prior to chemical processing of the uranium ore, the values specified below may be used in lieu of those determined in accordance with 1., above, or those specified in 2. and 3., above.

a. For purposes of Table I, Col. 1-1×10^{-10} μc / ml gross alpha activity; or 2.5×10^{-11} μc / ml natural uranium; or 75 micrograms per cubic meter of air natural uranium.

b. For purposes of Table II, Col. 1-3×10^{-12} μc / ml gross alpha activity; or 8×10^{-13} μc / ml natural uranium; or 3 micrograms per cubic meter of air natural uranium.

5. For purposes of this note, a radionuclide may be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide

in the mixture (C_A) to the concentration guide for that radionuclide specified in Table II of this annex (CG_A) does not exceed 1/10,

$$\text{i.e.,} \quad \frac{C_A}{CG_A} \leq \frac{1}{10}$$

and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed 1/4,

$$\text{i.e.,} \quad \frac{C_A}{CG_A} + \frac{C_B}{CG_B} + \quad \ldots\ldots \leq \frac{1}{4}$$

6. Conversion from μ Ci/cc to p Ci/m^3 for air and p Ci/l for water are as follows:

   a. Air - μ Ci/cc X 10^{12} = p Ci/m^3

   b. Water - μ Ci/cc X 10^9 = p Ci/l

7. Concentrations may be derived for unlisted radionuclides provided yearly dose limits in I, A. and II, A. are used and the methods are consistent with those recommended by the FRC and ICRP.

U. S. ATOMIC ENERGY COMMISSION
AEC MANUAL

Oak Ridge Operations Office

Volume: 0000 General Administration OR-0524
Part: 500 Health and Safety

Chapter OR-0524 STANDARDS FOR RADIATION PROTECTION

0524-03 Responsibilities and Authorities.

034 Managers of Field Offices:

a. Division Directors, Area Managers, and the Extension Manager, DTIE, in the administration of their direct and contract activities, comply with the provisions of Chapters AEC and OR-0524 and assure that:

1. AEC and contractor personnel under their jurisdiction, and the general public, are protected against radiation exposure, and that necessary measurements are made to determine conformance with Chapter and Appendix AEC-0524. (R)

2. Operations for which they are responsible are covered by approved emergency plans which are compatible with AEC Appendix 0524.

3. Except when emergency conditions do not allow sufficient time, contractors submit written requests for planned or anticipated deviations to AEC Appendix 0524 standards to their Contract Administrator. (R)

4. Contractor representatives responsible for operations are authorized to take appropriate measures during emergency situations.

b. The Director, Safety Division:

1. Provides advice and assistance in interpreting and applying the instructions pertaining to the permissible exposure to radiation.

2. Appraises contractor procedures for maintaining compliance with the routine and emergency exposure criteria of Chapter and Appendix AEC-0524. (R)

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(R) 3. Provides required reports and justifications to DOS Headquarters regarding exceptions or deviations from the requirements of Chapter and Appendix AEC-0524.

0524-05 Basic Requirements.

051 Applicability.

The provisions of Chapters AEC and OR-0524 are applicable to all Divisions, Area Offices, and DTIE, and to AEC contractors as defined in Subsection AEC-0524-041.

(N) 0524-06 National Emergency Application.

During a National Emergency, as defined in Section AEC-0601-04, the provisions of this Chapter and Appendix are not mandatory.

APPENDIX I

EXERPT FROM ORNL CF-72-6-16
ESTIMATED SAFE MASS LIMITS FOR ACTINIDE ISOTOPES

APPENDIX

(D. W. Magnuson)

Estimated Safe Mass Limits for Actinide Isotopes

The minimum critical mass limits for several actinide isotopes have been calculated using a very simple technique[1] and have been published with recommended subcritical limits.[2] The method is dependent on 2200 m/sec capture and fission cross sections and the value of ν for the isotope, the hydrogen absorption cross section, the neutron age-to-thermal, and the neutron diffusion length.

Since the values of these cross sections are subject to revision, revised estimates of the minimum critical masses were made with different cross sections. In the calculations reported here the neutron age-to-thermal energy[3] was 26.5 cm^2 and the extrapolation distance including water reflector savings was 5.9 cm.[4] The values of these parameters were not given for the previous estimates and were probably slightly different. The comparison of all of these calculations of the minimum critical masses is given in Table 1 with new subcritical limits established by dividing by 4.6, the typical factor of 2.3 plus an additional factor of 2 because of the large uncertainties in cross sections. The use of the two-group buckling theory for small systems is questionable and is another reason for having a larger safety factor than usual.

The estimates given here for the minimum critical masses do not include the effects of resonance absorption and in general this effect gives rise to increased minimum values. These estimates are also for essentially pure isotopes. In general, the even isotopes for the even atomic numbered elements have small thermal fission cross sections and the presence of such isotopes has been ignored. Similar to isotopic dilution of ^{235}U with ^{238}U, the increase in critical mass can be large for small percentages of the fissile isotope.

It is believed that reliable cross-section data must be obtained on all actinide isotopes which will be present in actinide solutions before more accurate criticality parameters can be calculated.

APPENDIX

Minimum Critical Mass Estimates and Subcritical Limits for Fissile Isotopes.

Isotope	Value of ν	Experimental	Calculated by Clark		Calculated by This Report						Recommended Subcritical Limit (g) Ref. 2	Recommended Subcritical Limit (g) This Work
Cross Section Reference		5	2	2	6	7	8	9	2	8		
^{233}U	2.482[a]	600			479							250.0
^{235}U	2.432[a]	800			663							350.0
^{239}Pu	2.874[a]	500			431							200.0
^{241}Pu	2.89[b]					420		289				125.0
^{242m}Am	3.18[c]		23	21.2		36.8					10	5.0
^{243}Cm	3.28[c]		213	227		292					150	50.0
^{245}Cm	3.30[c]		42	38.6		49.7	41.3	58.3	19.8[d]		25	4.3
^{247}Cm	3.31[c]		159	150		191	2720	1890			120	32.0
^{249}Cf	3.70[c]		32	30.8		16.9[e]	14.7			12.8[f]	20	2.8
^{251}Cf	4.48[c]		10	9.7		12.7	6.1	26.6			3	1.0
^{253}Cf								10.5[g]				2.0

a. The value of ν was taken from Ref. 10.
b. The value of ν was assumed to be 2.89, the value obtained from ^{239}Pu by the method described in Ref. 2.
c. The value of ν was taken from Ref. 2.
d. The value of ν was assumed to be 3.83 from Ref. 11.
e. The value of ν was assumed to be 4.46, the value obtained from ^{251}Cf by the method described in Ref. 2.
f. The value of ν was assumed to be 4.60 from Ref. 11.
g. The value of ν was assumed to be 4.50, the value obtained from ^{251}Cf by the method described in Ref. 2.

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2. H. K. Clark, Trans. Am. Nucl. Soc. 12, 886 (1969).

3. R. Gwin and D. W. Magnuson, Nucl. Sci. Eng. 12, 364 (1962).

4. H. C. Paxton et al., Critical Dimensions of Systems Containing U^{235}, Pu^{239}, and U^{233}, TID-7028, Fig. 3, p. 6 (1964).

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